NEW SERVICE – EW+WW INDEX ON FLOPPY DISK

ELECTRONICS WORLD + WIRELESS WORLD

Denmark DKr. 70.00
Germany DM 15.00
Greece Dra.760
Holland Dfl. 14
Italy L. 7300
IR £3.30
Spain Pts. 780
Singapore SS 12.60
USA $6.70

A REED BUSINESS PUBLICATION
SOR DISTRIBUTION

FEBRUARY 1995 £1.95

VIDEO ON DEMAND

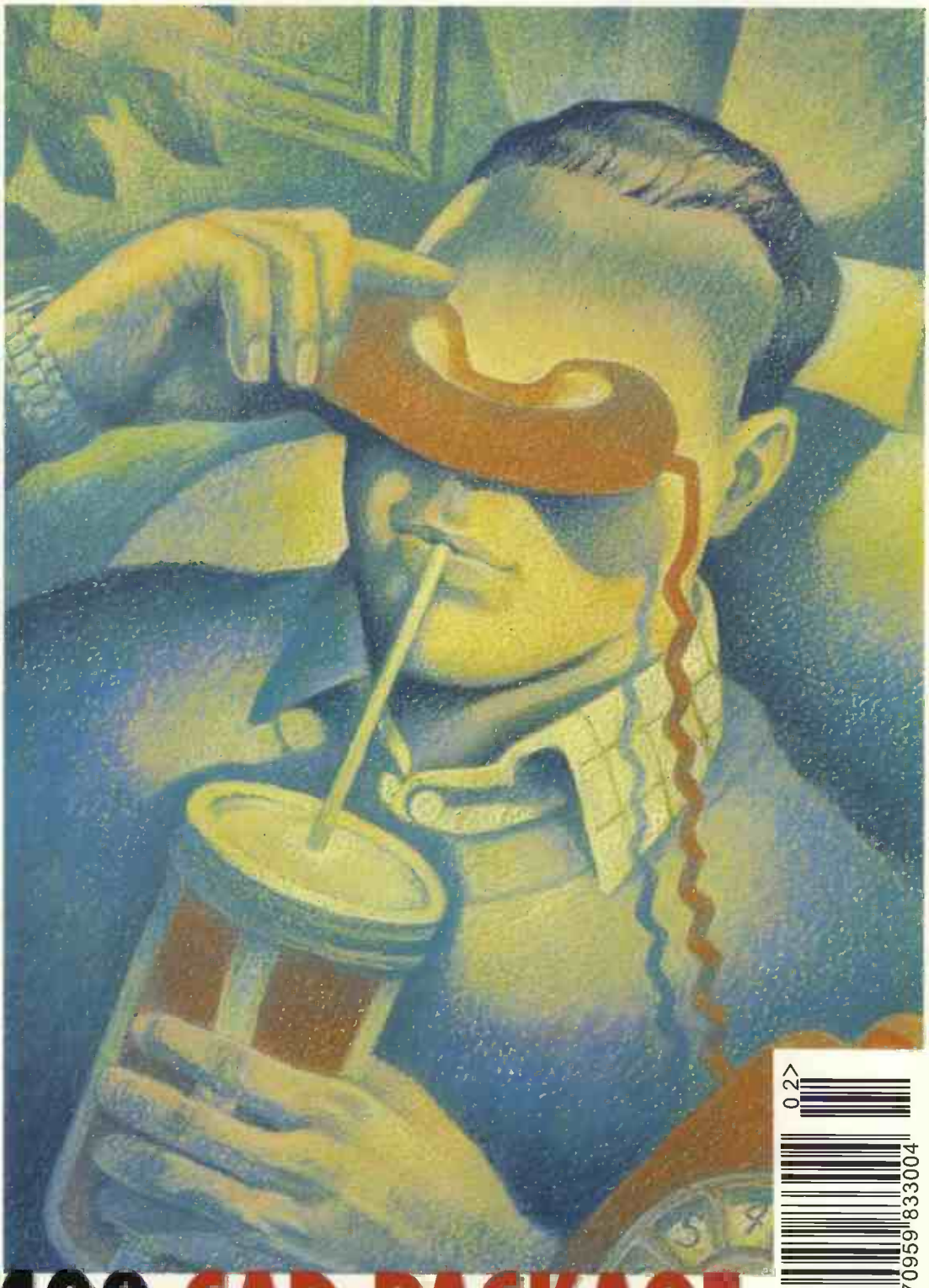
The audio power interface

New null filter design

Data logging via the PC

Combiners and splitters for RF

Analogue design with a 5V supply



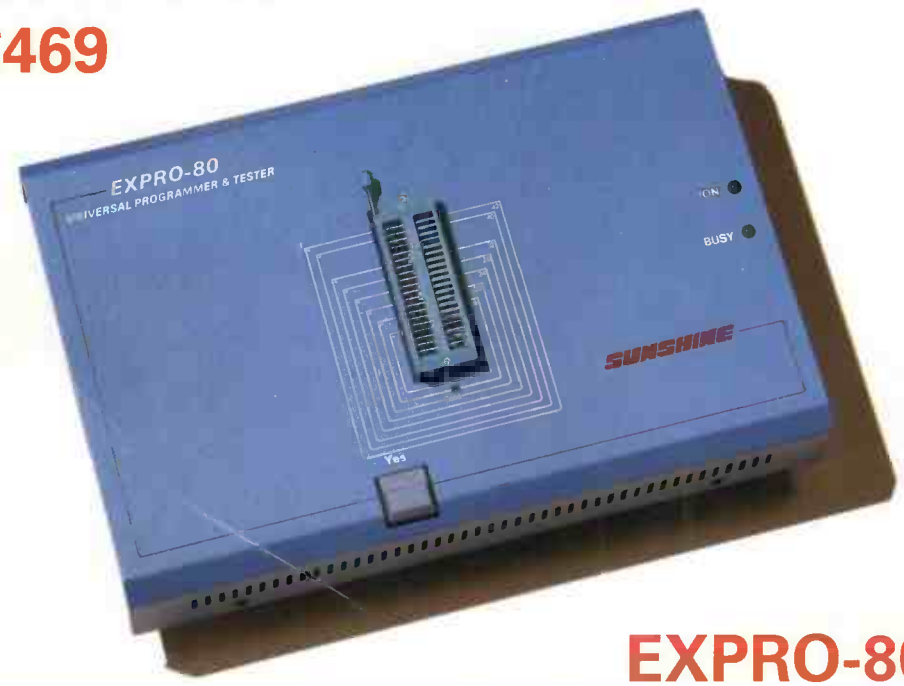
WIN A £400 CAD PACKAGE

02
9 770959 833004

NEW! FROM THE MAKERS OF THE WORLDS BEST SELLING UNIVERSAL PROGRAMMING AND TESTING SYSTEM

* Ability to program 3 volt devices.
* Calibration software to comply with ISO9000.
* Batch software for production programming.
* High quality 42 pin Textool zero insertion force sockets.
* Rugged metal housing and heavy duty screened cable.
* Ground control circuitry using relay switching.
* Protection circuitry to protect against wrong insertion of devices.
* Speed optimised range of programming algorithms.
* Supplied with MICROTEC disassemblers for Z8, 8085, 8048, 8051, 6809 & 68HC11.
* Programs PIC16 series without adaptor.
* Software supplied to write own test vectors for custom ICs and ASICs etc.
* One model covers the widest range of devices, at the lowest cost.
* Over 2000 different devices (including several hundred MPU's) supported.
* Tests and or identifies a wide range of logic devices.
* High speed PC interface card designed for use with all types of PC.
* No need to tie up a slow parallel port.
* More Sunshine programmers sold worldwide than any other of its type.
* UK users include BT, IBM, MOD, THORN EMI, MOTOROLA, SANYO, RACAL.
* Two year free software update.
* Free demo disk with device list available.

NOW ONLY £469



EXPRO-80

The Sunshine Expro-80 Universal Programmer and Tester is the 42 pin version of the immensely popular Expro-60/PC-82. Following that success, the Expro-80 is a PC-based development tool designed to program and test more than 2000 ICs. The culmination of over 8 years production experience has resulted in perfecting this rugged, classically designed programmers' programmer.

Volume production has now enabled us to offer this powerful programmer at a very competitive price for a product of such high quality. The Expro-80 has undergone extensive testing and inspection by various major IC manufacturers and has won their professional approval and support. Many do in fact use the Expro-80 for their own use!

The Expro-80 can program E/EPROM, Serial PROM, BPROM, DSP, PLD, EPLD, PEEL, GAL, FPL, MACH, MAX and MPU. It comes with a 42 pin DIP/SDIP socket capable of programming devices with 8 to 42 pins. It even supports EPROMs to 16Mbit, the PIC16 series of MPUs and many many more without the need of an adaptor. Adding special adaptors, the Expro-80 can program devices up to 84 pins in DIP, PLCC, LCC, QFP, SOP and PGA packages.

The unit can also test digital ICs such as the TTL 74/54 series, CMOS 40/45 series, DRAM (even SIMM/SIP modules) and SRAM. Furthermore it can perform functional vector testing of PLDs using the JEDEC standard test vectors created by PLD compilers such as PALASM, OPALjr, ABLE, CUPL etc. or by the user. The Expro-80 can even check and identify unmarked devices.

The Expro-80's hardware circuits are composed of 42 set pin-driver circuits each with control of TTL I/O and "active pull up", D/A voltage output, ground, noise filter circuit and OSC crystal frequency.

New features include negative programming voltages, 3 volt programming ability, protective circuitry for ICs incorrectly inserted, calibration software to comply with ISO9000, new six layer PCB and voltage clamping to banish noise and spikes.

A dedicated plug in card with rugged connecting cable ensures fast transfer of data to the programmer without tying up a standard parallel or serial port. Will work in all types of PC. In addition, there is now the Link-P1 enabling the programmer to be driven through the printer port. Ideal for portables and PC's without expansion capability.

The pull-down menus of the software makes the Expro-80 one of the easiest and most user-friendly programmers available. A full library of file conversion utilities is supplied as standard.

Sunshine's team of over 20 engineers are continually developing the software, enabling the customer to immediately program newly released ICs.

Citadel, a 33 year old company are the UK agents and service centre for the Sunshine range of programmers, testers and in circuit emulators and have a team of engineers trained to give local support in Europe.

ORDERING INFORMATION

Expro-80 complete with interface card, cable, software and manual only **£469**

Please add £8 carriage (by overnight courier) for UK orders, £30 for export orders and VAT where applicable.

ACCESS, MASTERCARD, VISA or CWO. Official orders are welcome from Government bodies and local authorities.

CP Citadel

CITADEL PRODUCTS LTD
DEPT. WW, 50 HIGH ST.,
EDGWARE, MIDDX. HA8 7EP.

Phone now on: 0181 951 1848/9

Access MasterCard VISA

Our stocked range of own manufactured and imported Sunshine products include:

* Super fast EPROM Erasers.
* 8Mbit EPROM Programmers:
  ie: 1 gang £149
  4 gang £229
  8 gang £399
* Battery operated portable EPROM programmers.
* "In circuit" Emulators.
* Handy pocket IC testers.

CONTENTS

FEATURES

Cover: Hashim Akib

ADSL – AN EASY ROUTE TO VIDEO ON DEMAND.....102
Television down the telephone line. ADSL technology is at the heart of BT's forthcoming trials for video on demand. It enables television signals to be sent down 'phone wires – a technique that Geoff Lewis believes could become a world standard.

CATCHING DATA VIA LPT1 107
Interfacing via the pc's printer port, Pei An's data acquisition system for capturing 16 channels with 12-bit resolution is easily transferred between machines. As a bonus, this analogue signal capture system also offers an 8bit digital output port for control.

BETWEEN AMPLIFIER AND SPEAKER 114
Loading an amplifier with a moving-coil loudspeaker involves reactances, impedances and phase effects – all conspiring to upset stability. Ivor Brown shows how to minimise the undesirable effects.

NEW NULL FILTER REPLACES TWIN-T 119
Suitable for distortion measurement, Bengt Olsson's high-performance null filter avoids the tedious adjustments needed when twin-T filters are used.

IMPROVING ANALOGUE CONVERSION.....134
Rather than using a cad-designed post-conversion filter for good hf performance with clocked dacs, Michael Batty opts for a much simpler, separate correction filter.

CIRCUITS BY DESIGN.....136
Before cad, designing filters was tedious, to say the least. Owen Bishop shows how to get the best out of modern Windows-based cad software when engineering filter circuits.

WIN SPICE AGE FOR WINDOWS.....140
Answer a few questions correctly and you could win a copy of the professional version of *Spice Age for Windows* worth over £400.

A QUESTION OF BALANCE.....142
Whether two rf sources are being brought into, or taken from, a single port, load balancing is essential. Steve Winder provides some tips for designing rf combiners and splitters.

PROGRAMMING FOR TELETEXT ON THE PC...146
Complementing his previous hardware description, Laurence Cook discusses how to design software for controlling his teletext adapter for the pc.

CIRCUITS FOR SMALL-SIGNAL AMPLIFIERS.....155
Having succeeded in designing your small-signal amplifier and determining its source and load impedances you need circuits to realise those impedances. Norm Dye and Helga Granberg present the final extract from their book *RF Transistors – Principles and Practical Applications*.

ANALOGUE DESIGN WITH A 5V SUPPLY 162
While low supply voltages are common in the digital world, they are only just spreading to analogue devices. Walt Jung and James Wong look at the limitations imposed when designing circuits to run from a single low-voltage supply.

REGULARS

COMMENT.....91
Video games

NEWS.....92
ADSL improvement, No follow through for double science, Deep-field video microscopy, Intelligent agents under development, World's smallest power amp, War on video cd format.

RESEARCH NOTES.....98
Teleassistance for robots, Submarine swims like a fish, Testing time for microwave circuits. Does electronics make us worse drivers?

DESIGN BRIEF.....122
Tweaking the diode detector. Ian Hickman finds that the diode detector has a lot to offer – having found a way round forward-voltage offset.

CIRCUIT IDEAS.....128
Jump-starting a rom-less microcontroller, Quadrature-output oscillator for sine waves, Digital thermometer using low-noise bridge amplifier, Active photodiode source, Preventing battery over-discharge.

LETTERS.....149
A compulsive comment, Sine post, Hand-Shakey, Electrolytic detection, Coil question. Heartfelt criticism, Unacceptable terms and Slew review – correspondence on Doug Self's amplifier design.

NEW PRODUCTS.....167
Classified run-down of a wide selection of new digital and analogue electronics products presented with emphasis on ease of selection.

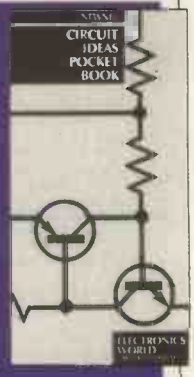
In next month's issue:

Free Circuit Ideas Pocket Book – a selection of circuit ideas from *EW+WW* brought together in one handy volume.

- Doug Self discusses building power amplifiers for supply immunity.
- RS232 communication is faster using psk, as Lanka Kumar *et al* show.
- Looking into transmission lines – Geoffrey Billington explains.

Fill in the newagents' order form between pages 144 and 145.

MARCH ISSUE – ON SALE February 23



PHYTEC hitex

High Quality Low Cost 8051 & SABC166 Modules

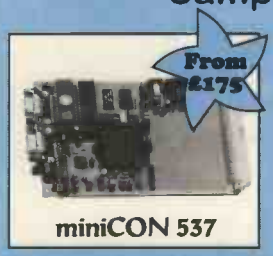
Phytec modules are low cost prototyping and production cards, available for today's most popular microcontrollers, including the 8051, 68HC11 and 80C166 families.

Each of the eurocard-sized prototyping boards is available as part of a development kit containing an assembler, ANSI C compiler and source level debugger.

Once your product has been developed, the same prototyping hardware is available as a surface mount production module, ready to be incorporated into your final design.

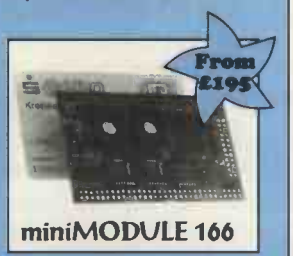
With countless uses in the fields of measurement, control and monitoring, Phytec modules are an ideal, cost-effective solution for rapid product prototyping and development.

Sample Modules



Board for Siemens SAB80C537. With A/D and D/A, 2 serial ports, 5 digital I/O ports, up to 64K EPROM, 160K RAM and 32K EEPROM

Board for Siemens SAB80C166. 40Mhz, 16Bit Controller, 100ns interrupt latency, 256K RAM, real time clock.

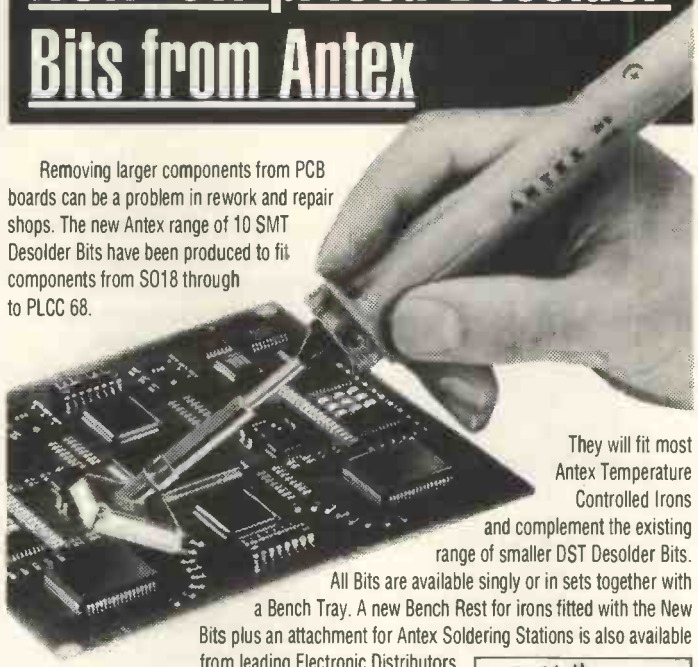


Credit card sized production modules based on the miniCON development boards, with a low-power, surface mount design. Migrate from a prototype to finished hardware, vastly reducing time for marketing and development costs.

Hitex (UK) Ltd
Warwick University Science Park, Coventry, CV4 7EZ
Tel: 01203 692066 FAX: 01203 692131 BBS: 01203 690026

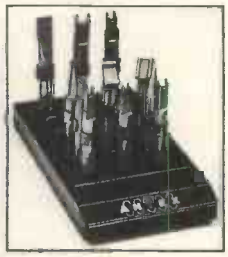
CIRCLE NO. 104 ON REPLY CARD

New low-priced Desolder Bits from Antex



Removing larger components from PCB boards can be a problem in rework and repair shops. The new Antex range of 10 SMT Desolder Bits have been produced to fit components from SO18 through to PLCC 68.

They will fit most Antex Temperature Controlled Irons and complement the existing range of smaller DST Desolder Bits. All Bits are available singly or in sets together with a Bench Tray. A new Bench Rest for irons fitted with the New Bits plus an attachment for Antex Soldering Stations is also available from leading Electronic Distributors.



ANTEX
Antex (Electronics) Ltd.
2 Westbridge Industrial Estate, Tavistock, Devon PL21 8DE
Tel: (0822) 613565 Fax: (0822) 617598

CIRCLE NO. 105 ON REPLY CARD

PIC ICE II* In Circuit Emulator for **PIC16C54-55-56-57-71-84.** Replaces all **18** or **28** pin PICs. All ports Bi-directional, OSC2 output, RTCC input.
On board A/D converter for PIC16C71.
Supplied with **PICDEV54** and **PICDEV71** software, manual, connecting leads and headers, ASM examples, and hardware circuit projects. **£159.95**

PIC ICE 18P In-Circuit Emulator for 18 pin PICs only no A/D. Plugs into the printer port appears to the target system as a normal Pic device including OSC2 and RTCC in/out.
Runs in real time from the IBM PC changes made to File registers reflected on target.
Supplied with Development software **PicDev 54-57** and **PicDev 71/84** **£69.95**

PICPROG* Programs Pic **16C54-55-56-57-71-84.** Centronics port interface.
Powerful editing software to Read, Write & Copy Pic devices including data memory in Pic16C84.
Top quality components used throughout including production ZIF socket.
Now includes a Text Editor/Assembler for all above PICs. **£79.95**
Requires external power 15-20v AC or DC @ 250 ma. (optional extra £6.50).

MEGAPROM programmer. **EPROMS, E2PROMS,** and **FLASH** memories from 2k (2716) to 8 Meg (27C080). Runs on IBM PC via the centronics port using standard printer cable.
Works on all PC compatibles, laptops, and notebooks. No special port requirements.
Uses approved programming algorithms. Very fast program & verify 27C512 = 45 seconds.
Full screen editor software supports Bin, Intel Hex, Motorola S and Asc formats.
Top quality components used throughout including production ZIF socket. **£99.95**
Requires external power supply 18-25v AC or DC @ 250ma. (optional extra £6.50).

EPROM EMULATOR Works on **ANY** computer with centronics printer port. Data sent to the printer appears in the target board Eprom socket. Emulates from **1k** to 32k Byte (27C256) roms, board switchable.
Very fast download. Works with or without our Development software. **£59.95**

PC SCOPE. Convert your IBM PC into a Storage Oscilloscope with our A/D converter. Simply plug into the printer port (no power required). Sample rate 10k to 30k per second.
Software supplied for Scope and Voltmeter. A/D source to write your own programs. **£29.95**

DEVELOPMENT SOFTWARE **£19.95**
Develop software on your IBM PC for other Microprocessors, Controllers, Pic's etc.
Software has fully integrated Text Editor, Assembler, Disassembler, and Simulator.
The Simulator displays all registers along with disassembled code program counter, Condition code register. The user can single-step, go with breakpoints, watch memory, etc. change any/all registers/memory locations at any time (on the fly).
Code can be Saved to disk and/or downloaded directly to our EPROM Emulator. All software supplied with sample. ASM files, and user documentation/manual.
Very powerful software as supplied to universities, colleges ITECS and Industry.
Available for the following:-

MCS8051/52/552	**MCS8048/49**	**PIC16C71/84**
PIC16C54/5/6/7	**HD63/6809**	**R6502**

Starred items also available from FARNELL (Leeds).
All hardware carries a 12 months parts and labour Guarantee. No Vat payable. Please add £1.50 for Carriage.

CREDIT CARD ORDERS SAME DAY DESPATCH

JOHN MORRISON DEPT WW
4 REIN GARDENS, TINGLEY,
WEST YORKSHIRE WF3 1JR
TEL (or FAX) 0532 537507

VISA

CIRCLE NO. 106 ON REPLY CARD

Video games

BT's Head of Research, Dr Alan Rudge, – formal title MD Development and Procurement – stands out like a sore thumb amongst BT's other bosses. He talks with the frankness and honesty of an engineer, not the veneered smarm of an accountant or professional manager.

In early December, BT celebrated ten years of privatisation. At one event, 'A glimpse of the future', Rudge described his job. Because he cannot personally oversee all research projects at Martlesham, he gets most closely involved in the ones that go wrong. "It's like being at the end of a sewer pipe", said Rudge, before demonstrating a few of the projects that are going well.

One is 'remote foetal scanning'. Guests at the top of the BT Tower watched high-quality moving ultrasound images transmitted in real time by telephone wire from a hospital on the Isle of Wight. The pictures of a 15 week-old foetus came down the wire in a two-megabit stream.

Earlier Rudge had talked of BT's plans for a Video On Demand trial this summer (1995), using 2Mbit ADSL and covering 2500 homes in the Ipswich area. "It is a market trial," stressed Rudge, "not an experiment". Presumably then, the foetal images were streaming from the Isle of Wight thanks to VOD technology?

No. BT had ganged together 30 ISDN channels. Why? Because even though the VOD market trial was still only six months away, BT could not muster a single pair of ADSL codec/modems and found it easier to sledgehammer the problem with 30 ISDN lines.

Barely able to disguise his frustration at the Government's refusal to promise BT the right to earn money from piping entertainment through its network after 2001, Rudge became even more frank about the practical limitations of VOD.

"ADSL is not economic for 30 million customers. The cable companies are digging up the roads and putting in copper. That is the technology we are trying to get away from. We have £15 billion, the price of two Channel Tunnels, earmarked for an optic fibre highway. We don't want to invest too much in an interim solution. But we need to know where we stand after 2001 – and how we can earn revenue from our highway".

The consumer electronics industry is already using the same MPEG compression technology that makes ADSL VOD possible, to release movies of better-than VHS quality on pairs of one hour five inch CDs. The recently announced Philips/Sony High Density Digital Video Disc puts a full length movie onto a single five inch CD, with broadcast quality.

At pressing costs of under 50p per disc, Video CD provides a very cheap way of distributing movie material by retail sale, mail order or corner store rental. To compete, VOD must offer similar quality, on the same or more modern movies, at similar price points.

Prototype VOD codec/modems currently cost around $10,000. At the recent CD-i conference in Dusseldorf, panelists from Philips and Motorola were arguing over whether consumer box prices could fall to below $750 by the end of the century.

Rudge is right. However exciting VOD and the enabling technology may be, and however excited BT's publicity machine may get, using old-fashioned twisted pairs to carry VHS quality pictures is an interim solution which sucks investment from the long-term strategy of replacing copper with fibre.

BT feels confident that the Labour leaders-in-waiting have grasped this point. The best leaving present the current Government could give Britain before it collapses into a lost election would be to move fast with a clear challenge to BT and the Labour party – 'OK, BT; if you put your money where your mouth is, and pledge to 'fibre' the country by the end of the century, we pledge that you can use that fibre in the next century, in any way you like. And we will put it to a Commons vote so that Labour can't reverse that policy.' ■

Barry Fox

EDITOR
Martin Eccles
081-652 3128

CONSULTANT
Frank Ogden

DESIGN & PRODUCTION
Alan Kerr

EDITORIAL ADMINISTRATION
Jackie Lowe
081-652 3614

ADVERTISEMENT MANAGER
Richard Napier
081-652 3620

DISPLAY SALES EXECUTIVE
Malcolm Wells
081-652 3620

ADVERTISING PRODUCTION
Christina Budd
081-652 8355

PUBLISHER
Mick Elliott

EDITORIAL FAX
081-652 8956

CLASSIFIED FAX
081-652 8956

SUBSCRIPTION HOTLINE
0622 721666
Quote ref INJ

SUBSCRIPTION QUERIES
0444 445566

NEWSTRADE DISTRIBUTION
Martin Parr
081 652 8171

BACK ISSUES
Available at £2.50
081 652 3614

ISSN 0959-8332

REED BUSINESS PUBLISHING

Electronics World + Wireless World is published monthly. By post, current issue £2.25, back issues (if available) £2.50. Orders, payments and general correspondence to **L333, Electronics World + Wireless World, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS.** Tlx:892984 REED BP G. Cheques should be made payable to Reed Business Publishing Group.
Newstrade: Distributed by Marketforce (UK) Ltd, 247 Tottenham Court Road London W1P 0AU 071 261-5108.
Subscriptions: Quadrant Subscription Services, Oakfield House, Perrymount Road, Haywards Heath, Sussex RH16 3DH. Telephone 0444 445566. Please notify change of address. Subscription rates 1 year (normal rate) £30 UK and £43 outside UK.
USA: $52.00 airmail. Reed Business Publishing (USA), Subscriptions office, 205 E. 42nd Street, NY 10117.

Overseas advertising agents: France and Belgium: Pierre Mussard, 18-20 Place de la Madeleine, Paris 75008. United States of America: Ray Barnes, Reed Business Publishing Ltd, 205 E. 42nd Street, NY 10117.Telephone (212) 867-2080. Tlx 23827.
USA mailing agents: Mercury Airfreight International Ltd Inc, 10(b) Englehard Ave, Avenel NJ 07001. 2nd class postage paid at Rahway NJ Postmaster. Send address changes to above.
Printed by BPCC Magazines (Carlisle) Ltd, Newtown Trading Estate, Carlisle. Cumbria, CA2 7NR
Typeset by Wace Publication Imaging 2-4 Powerscroft Road, Sidcup, Kent DA14 5DT

©Reed Business Publishing Ltd 1995 ISSN 0959 8332

Aware proposes ADSL improvement

M-band wavelet transforms are being used by Aware, the Massachusetts-based signal processing software developer, to provide radical improvements to the performance of the adsl modulation technique used by BT in its video-on-demand service.

Adsl, or asymmetric digital subscriber loop signalling, is a technique which enables a broadband signal, theoretically up to 6Mbit/s, to be transmitted over copper telephone lines from the exchange to the subscriber's home. BT in the UK and Bell Atlantic in the US are using adsl systems supplied by Westell International to transmit a video channel carrying video on demand and home-shopping services to subscnbers.

Current adsl systems use carrierless amplitude and phase (cap) modulation which effectively divides the 2.048Mbit/s channel data rate between two carriers of different phase and amplitude. BT believes that cap will support a 2Mbit/s: video channel over 6km of copper pair which represents 91 per cent of its subscriber lines.

A multi-carrier version of adsl, although more expensive than cap-based systems, is able to support data rates up to 6.9Mbit/s and is more immune to line interference.

Aware, which along with fellow US software developer Amarti, as well as Analog Devices and Westell, has been developing the technique known as discrete multi-tone (dmt), is proposing a new approach based on wavelet rather than Fourier signal processing techniques. Drawbacks with dmt have led the US developer to investigate the use of the alternative discrete wavelet multitone (dwmt) modulation technique.

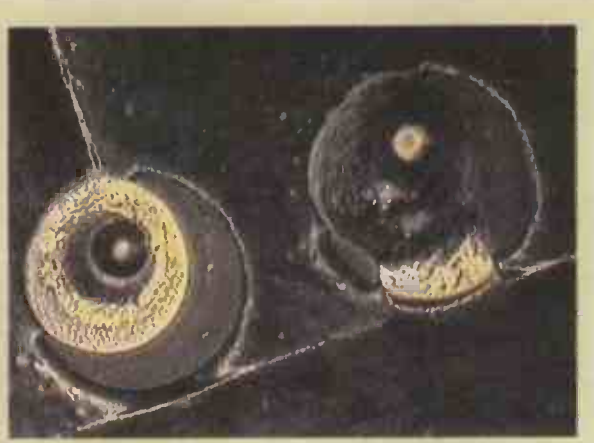
The attraction of dwmt, using an M-band wavelet transform, is that it provides both a longer symbol duration and lower sidelobes than the fft-based dmt. The wavelet methodology provides a more practical implementation of classical Fourier transforms.

Aware claims that use of M-band wavelet transforms instead of fft in the classic discrete multi-tone technique produces a 4dB improvement in signal margin in a practical adsl multi-carrier transceiver. According to Aware, the computational complexity of the wavelet transform is around one half that of the Fourier transform.

Aware quantifies performance improvement in terms of the interference between sub-channels and symbols for dmt and dwmt systems of similar complexity. Average improvement is around 6dB in signal sensitivity and Aware quotes a minimum improvement figure of 4dB.

Aware also says that the use of Wavelet instead of Fourier transforms does not threaten compatibility with the other elements of the adsl transceiver design, as proposed by Amarti which is working with Motorola.

Richard Wilson, *Electronics Weekly*



Cambridge Technology Systems claims that deep field video microscopy, a system it markets in the UK for Scientific Instruments, can be used to reveal micro-defects in solder adhesion and integrity – particularly at the contact points between miniature components and pcbs. The right hand side of the photo shows a sound micro-pin soldered connection; on the left is a poor one which, due to lack of solder volume, shows early signs of failure. (The solder appears black in the photo.)
This photo was taken at 80× magnification. The magnification range can be extended to 1,000× if necessary, to resolve fine surface detail.

Double science increase not followed through

Although there are now more young people in the UK studying science to the age of 16, fewer of them are carrying on to take science A levels. This is one of the main findings of a report, 'The Impact of Double Science' published by the Engineering Council and written by two authors from the University of Manchester.

There has been a marked growth in entries for science GCSE since compulsory science to the age of 16 was introduced. The increase in entries is particularly marked in double science; these have risen from 22.3% in 1989 to 82%. The term 'double science' indicates the amount of curriculum time allocated to science: the equivalent of two subjects.

However, at A level, physics entries have fallen by 18.7% over the last four years and chemistry entries by 8.1%. The most likely reason for this is the gap between GCSE and A level. Other possible reasons are the upheaval in science education that takes place between 14 and 16, poor teaching, signals from the labour market and the rigidity of the three A-level system. All are likely to have contributed.

The lack of follow on to science A levels has to be seen in the light of an overall rise in A level entries since 1962, from 11 to 31% of the age group. The report's authors suggest bridging the gap between GCSE and A level by recording performance in the double award separately for biology, chemistry and physics or by aligning the two better so that A levels begin where the GCSE leaves off. It is also suggested that students should take five subjects at A level, rather than three, giving them more choice of subject as well as leading on more naturally from GCSE.

Surplus always wanted for cash!

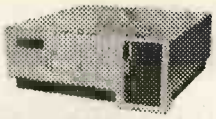
THE *ORIGINAL* SURPLUS WONDERLAND!

THIS MONTH'S SELECTION FROM OUR VAST EVER CHANGING STOCKS

Surplus always wanted for cash!

LOW COST PC's - ALL EXPANDABLE - ALL PC COMPATIBLE

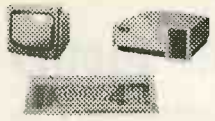
SPECIAL BUY
AT 286
40Mb HD + 3Mb Ram



LIMITED QUANTITY only of these **12Mhz HI GRADE 286** systems Made in the USA to an industrial specification, the system was designed for *total reliability.* The compact case houses the motherboard, PSU and EGA video card with single 5¼" **1.2 Mb** floppy disk drive & **integral 40Mb hard disk drive** to the front. Real time clock with battery backup is provided as standard. Supplied in good used condition complete with **enhanced keyboard, 640k + 2Mb RAM, DOS 4.01 and 90 DAY Full Guarantee.** *Ready to Run!*
Order as HIGRADE 286 **ONLY £149.00** (E)
CALL FOR QTY DISCOUNTS

Optional Fitted extras: VGA graphics card	£29.00
1.4Mb 3½" floppy disk drive (instead of 1.2 Mb)	£32.95
NE2000 Ethernet (thick, thin or twisted) network card	£49.00

PC SCOOP
COMPLETE
COLOUR SYSTEM
ONLY £99.00



A massive bulk purchase enables us to bring you a **COMPLETE ready to run** colour PC system at an unheard of price! **The Display Electronics PC99 system** comprises of fully compatible and expandable XT PC with 256k of RAM, 5¼" 360k floppy disk drive, **12" CGA colour monitor,** standard 84 key keyboard, MS DOS and all connecting cables - **just plug in and go !!** Ideal students, schools or anybody wishing to learn the world of PC's on an ultra low budget. **Don't miss this opportunity.** Fully guaranteed for 90 Days.
Order as PC99COL **£99.00** (E)

Optional Fitted extras: 640k RAM	£29.00
2nd floppy drive, specify 5¼" 360k or 3½" 720k	£29.95
Above prices for PC99 offer ONLY.	

SPECIAL OFFER

Computer Controlled
Laser Video Disk Player

One of the most **amazing** surplus deals that we ever been able to offer you! The **Philips VP410** LaserVision player, in as new condition, unit features full computer control, Plays standard **12" LaserVision** disks with **startling visual and audio quality** in two channel **stereo** or mono. When controlled by a computer, it may also be used as a versatile high quality storage / retrieval medium. It will play back either LaserVision CAV (active play) or CLV (Long Play) discs (which covers most types of commercially available video discs). Some of the many features of this incredible machine are:

- **RS-232 INTERFACE**
- **RGB / COMPOSITE VIDEO OUTPUT**
- **BNC+SCART INTERFACE**
- **PAL / RGB DECODER**
- **IR+WIRED REMOTE CONTROL**
- **FAST RANDOM ACCESS**

SPECIAL PURCHASE Only **£399.00** (F)

FLOPPY DISK DRIVES 3.5"- 8"

5.25" from £22.95 - 3.5" from £24.95

Massive purchases of standard 5.25" and 3.5" drives enables us to present prime product at industry beating low prices! All units (unless stated) are ***BRAND NEW*** or removed from often brand new equipment and are fully tested, aligned and shipped to you with a 90 day guarantee and operate from standard voltages and are of standard size. **All are IBM-PC compatible (if 3.5" supported on your PC).**

3.5" **Panasonic** JU363/4 720K or equivalent	£24.95(B)
3.5" **Mitsubishi** MF355C-L. 1.4 Meg. Laptops only *	£36.95(B)
3.5" **Mitsubishi** MF355C-D. 1.4 Meg. Non laptop	£29.95(B)
5.25" **Teac** FD-55GFR 1.2 Meg	£29.95(B)
5.25" **BRAND NEW Mitsubishi** MF501B 360K	£22.95(B)
* Data cable included in price.	
Shugart 800/801 8" SS refurbished & tested	£195.00(E)
Shugart 851 8" double sided refurbished & tested	£250.00(E)
Mitsubishi M2894-63 8" double sided *NEW*	£275.00(E)
Mitsubishi M2896-63-02U 8" DS slimline *NEW*	£285.00(E)

Dual 8" drives with 2 mbyte capacity housed in a smart case with built in power supply. Ideal as exterior drives! £499.00(F)

HARD DISK DRIVES

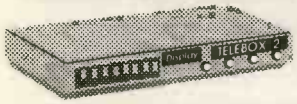
End of line purchase scoop! Brand new **NEC D2246** 8" 85 Mbyte of hard disk storage! **Full industry standard SMD interface.** Ultra hi speed data transfer and access time, replaces Fujitsu equivalent model. complete with manual. Only £299.00(E)

3.5" **FUJI** FK-309-26 20mb MFM I/F RFE	£59.95(C)
3.5" **CONNER** CP3024 20 mb IDE I/F (or equiv)RFE	£69.95(C)
3.5" **CONNER** CP3044 40mb IDE I/F (or equiv.)RFE	£89.00(C)
3.5" **RODIME** RO3057S 45mb SCSI I/F (Mac & Acorn)	£99.00(C)
5.25" **MINISCRIBE** 3425 20mb MFM I/F (or equiv.) RFE	£49.95(C)
5.25" **SEAGATE** ST-238R 30 mb RLL I/F Refurb	£69.95(C)
5.25" **CDC** 94205-51 40mb HH MFM I/F RFE tested	£69.95(C)
8" **FUJITSU** M2322K 160Mb SMD I/F RFE tested	£195.00(E)

Hard disc controllers for MFM , IDE, SCSI, RLL etc. from £16.95

THE AMAZING TELEBOX

Converts your colour monitor into a QUALITY COLOUR TV!!



TV SOUND & VIDEO TUNER!

The **TELEBOX** consists of an attractive fully cased mains powered unit, containing all electronics ready to plug into a host of video monitors made by makers such as **MICROVITEC, ATARI, SANYO, SONY, COMMODORE, PHILIPS, TATUNG, AMSTRAD** etc. The composite video output will also plug directly into most video recorders, allowing reception of TV channels not normally receivable on most television receivers* (**TELEBOX MB**). Push button controls on the front panel allow reception of 8 fully tuneable 'off air' **UHF** colour television channels. **TELEBOX MB** covers virtually all television frequencies **VHF** and **UHF including the HYPERBAND as used by most cable TV operators.** A composite video output is located on the rear panel for direct connection to most makes of monitor or desktop video systems. For complete compatibility - even for monitors without sound - an integral 4 watt audio amplifier and low level HI Fi audio output are provided as standard.

TELEBOX ST for composite video input type monitors	£34.95
TELEBOX STL as ST but with integral speaker	£37.50
TELEBOX MB Multiband VHF-UHF-Cable- Hyperband tuner	£69.95

For overseas PAL versions state 5.5 or 6mhz sound specification.
*For cable / hyperband reception Telebox MB should be connected to cable type service. Shipping code on **all** Teleboxes is (B)

FANS & BLOWERS

MITSUBISHI MMF-D6D12DL 60 x 25 mm 12v DC	£4.95 10 / £42
MITSUBISHI MMF-09B12DH 92 x 25 mm 12v DC	£5.95 10 / £53
PANCAKE 12-3.5 92 x 18 mm 12v DC	£7.95 10 / £69
EX-EQUIP 120 x 38mm AC fans - tested specify 110 or 240 v	£6.95
EX-EQUIP 80 x 38mm AC fans - tested specify 110 or 240 v	£5.95
VERO rack mount 1U x 19" fan tray specify 110 or 240v	£45.95 (B)
IMHOF B26 1900 rack mnt 3U x 19" Blower 110/240v NEW	£79.95

Shipping on all fans (A). Blowers (B). *50,000 Fans Ex Stock CALL*

IC's -TRANSISTORS - DIODES

OBSOLETE - SHORT SUPPLY - BULK

5,000,000 items EX STOCK

For *MAJOR SAVINGS* - SAE or CALL FOR LATEST LIST

VIDEO MONITOR SPECIALS

Superb quality 14" FOREFRONT MTS-9600 SVGA Multisync - Multimode monitor 0.28" dot pitch with resolution of **1024 x 768.** The multi mode input allows direct connection to a host of computers including **IBM PC's** in CGA, EGA, VGA & SVGA modes, **BBC, COMMODORE** (including Amiga 1200), **ARCHIMEDES** etc. The H version will also function with the **ATARI** in all modes inc **HI RES monochrome.** Complete with 'text' switching for WP use.(possible minor screen burns) Syncs down to 15 kHz. Supplied in **EXCELLENT** little used condition with full 90 day guarantee.
Order as MTS-9600 / H for ATARI £149.00 (E)
All modes as above Order as MTS-9600 / S £129.00 (E)

ELECTROHOME ECM-1211SBU 12" VGA multisync monitor with resolution **640 x 480.** Multi input selection; 9pin CGA/ EGA ; 15 pin VGA or 5 BNC connectors. 0.31 pitch. Compatible with PCs, Amiga, Atari and others. In good used condition (possible minor screen burns)90 day guarantee. ..... £99.00 (E)

KME 10" high definition colour monitors. Nice tight 0.28" dot pitch for superb clarity and modern styling. Operates from any 15.625 khz sync RGB video source, with RGB analog and composite sync such as **Atari,** Commodore Amiga, Acorn Archimedes & BBC. Measures only 13.5" x 12" x 11". **Only £125** (E) Good used condition. 90 day guarantee.
KME 10" as above for PC EGA standard £145.00 (E)

NEC CGA 12" colour IBM-PC compatible. High quality ex-equipment fully tested with a 90 day guarantee. In an attractive two tone ribbed grey plastic case measuring **15"L x 13"W x 12"H.** The front cosmetic bezel has been removed for contractual reasons.
Only £49.00(E)

20" 22" and 26" AV SPECIALS

Superbly made UK manufacture. PIL all solid state colour monitors, complete with composite video & optional sound inputs. Attractive teak style case. Perfect for Schools, Shops, Disco, Clubs, etc.In EXCELLENT little used condition with full 90 day guarantee.

20"....£135 22"....£155 26"....£185 (F)

12" Mono. Philips BM7542 /05G for CCTV **NEW £69.95 (C)**

DC POWER SUPPLIES

10,000 Power Supplies Ex Stock Call for info / list

Power One SPL200-5200P 200 watt (250 w peak).Semi open frame giving +5v 35a, -5v 1.5a, +12v 4a (8a peak), -12v 1.5a, +24v 4a (6a peak). All outputs fully regulated with over voltage protection on the +5v output. AC input selectable for 110/240 vac. Dims13" x 5" x 2.5". Fully guaranteed RFE. £85.00(B)

Power One SPL130. 130 watts. Selectable for 12v (4A) or 24 v (2A). 5v @ 20A. & 12v @ 1.5A. Switch mode.New.	£59.95(B)
Astec AC-8151 40 watts. Switch mode. +5v @ 2.5a. +12v @ 2a. -12v @ 0.1a. 6-1/4" x 4" x 1-3/4" RFE tested	£22.95(B)
Lambada LYS-PV-12 200 watt switch mode.+12V DC @ 29a semi enclosed, 10" x 5" x 5". RFE and fully tested.	£59.95(C)
Conver AC130. 130 watt hi-grade VDE spec.Switch mode.+5v @ 15a,-5v @ 1a,+12v @ 6a.27 x 12.5 x 6.5cms.New.	£49.95(C)
Boshert 13090.Switch mode.Ideal for drives & system. +5v@ 6a, +12v @ 2.5a, -12v @ 0.5a, -5v @ 0.5a.	£29.95(B)
Farnell G6/40A. Switch mode. 5v @ 40a.Encased	£95.00(C)

SPECIAL INTEREST

INTEL SBC 486/133SE Multibus 486 system. 8Mb Ram	£1975
Zeta 3220-05 A0 4 pen **HPGL** RS232 fast drum plotter	£1950
3M VDA - Video Distribution Amps.1 in 32 out	£375
Trio 0-18 vdc bench PSU. 30 amps. New	£470
Fujitsu M3041 600 LPM band printer	£1950
VG Electronics 1035 **TELETEXT** Decoding Margin Meter	£3750
Andrews LARGE 3.1 m Satellite Dish + mount (For Voyager!)	£950
RED TOP IR Heat seeking missile (not armed !!)	POA
Tektronix 1L30 Spectrum analyser plug in	£330
Thurlby LA 160B logic analyser	£375
GEC 1.5kw 115v 60hz power source	£950
Brush 2Kw 400 Hz 3 phase frequency converter	£850
Anton Pillar 75 kW 400 Hz 3 phase frequency converter	POA
Newton Derby 70 KW 400 Hz 3 phase frequency converter	POA
Nikon PL-2 Projection lens meter/scope	£750
Sekonic SD 150H 18 channel digital Hybrid chart recorder	£1995
HP 7580A A1 8 pen HPGL high speed drum plotter	£1850
Kenwood DA-3501 CD tester, laser pickup simulator	£350
Computar MCA1613APC 16mm auto iris lenses 'C' mount	£125
Seaward PAT 2000 dual voltage computerised PAT tester	£585

19" RACK CABINETS

Superb quality 6 foot 40U
Virtually New, Ultra Smart
Less than Half Price!

Top quality 19" rack cabinets made in UK by **Optima Enclosures Ltd.** Units feature designer, smoked acrylic lockable front door, full height lockable half louvered back door and removable side panels. Fully adjustable internal fixing struts, ready punched for any configuration of equipment mounting plus ready mounted integral 12 way 13 amp socket switched mains distribution strip make these racks some of the **most versatile we have ever sold.** Racks may be stacked side by side and therefore require only two side panels to stand singly or in bays
Overall dimensions are: 77-1/2" H x 32-1/2" D x 22" W. **Order as:**

OPT Rack 1 Complete with removable side panels.	£335.00 (G)
OPT Rack 2 Rack, Less side panels	£225.00 (G)

Over 1000 racks in all sizes 19" 22" & 24" 3 to 44 U. Available from stock !! Call with your requirements.

TOUCH SCREEN SYSTEM

The ultimate in **'Touch Screen Technology'** made by the experts - *MicroTouch* - but sold at a **price** below cost !! System consists of a flat translucent glass laminated panel measuring 29.5 x 23.5 cm connected to a PCB with on board sophisticated electronics. From the board comes a **standard serial RS232** or TTL output. The output continuously gives simple serial data containing positional X & Y co-ordinates as to where a finger is touching the panel - as the finger moves, the data instantly changes. The X & Y information is given at an **incredible matrix resolution of 1024 x 1024** positions over the screen size !!! So, no position, however small fails detection. A host of **available translation software** enables direct connection to a PC for a myriad of applications including: control panels, pointing devices, POS systems, controllers for the disabled or computer un-trained etc etc Imagine using your finger in 'Windows' instead of a mouse !! (a driver is indeed available !) ***The applications for this amazing product are only limited by your Imagination!!*** Supplied as a complete system including Controller, Power Supply and Data at an incredible price of only: ***RFE. Full Software Support Available - Fully Guaranteed*** **£145.00** (B)

LOW COST RAM & CPU'S

INTEL 'ABOVE' Memory Expansion Board. Full length PC-XT and PC-AT compatible card with **2 Mbytes** of memory on board. Card is fully selectable for Expanded or Extended (286 processor and above) memory. **Full data and driver disk supplied.** In good used condition fully tested and guaranteed.
Windows compatible. **Order as: ABOVE CARD** **£59.95**(A1)
Half **length 8 bit memory upgrade cards** for PC AT XT expands memory either 256k or 512k in 64k steps. May also be used to fill in RAM above 640k DOS limit. Complete with data.
Order as: XT RAM UG. 256k. £32.95 *or* **512k £38.95** (A1)

1 MB x 9 SIMM 9 chip 120ns	only	**£19.50**	(A1)
1 MB x 9 SIMM 3 chip 80 ns	only	**£23.50**	(A1)
1 MB x 9 SIMM 9 chip 80 ns	only	**£22.50**	(A1)
4 MB 70ns 72 pin simm module	only	**£89.00**	(A1)
***SPECIAL* INTEL 486-DX33 CPU**	*few only*	**£79.99**	(A1)

NO BREAK UNINTERRUPTIBLE PSU'S

Brand new and boxed 230 volts 1 KVa uninterruptible power supply system from **Densel. Model MUD 1085-AHBH.** Complete with sealed lead acid batteries in matching case. Approx time from interrupt is 15 minutes. Complete with full manual. **£575.00**(B)

EMERSON ACCUCARD UPS, brand new 8 Bit half length PC compatible card for all **IBM XT/AT** compatibles. Card provides DC power to all internal system components in the event of power supply failure.The Accusaver software provided uses only 6k of base RAM and automatically copies all system, expanded and video memory to the hard disk in the event of loss of power. When power is returned the machine is returned to the **exact status** when the **power failed !!** The unit features full self diagnostics on boot and is supplied **brand new,** with full, easy fitting instructions and manual.
Normally £189.00 *NOW!* **£69.00 or 2 for £120** (B)

Issue 13 of *Display News* now available - send large SAE - PACKED with bargains!

DISPLAY -ELECTRONICS-

ESTABLISHED 25 YEARS

LONDON SHOP
Open Mon - Sat 9:00 - 5:30
215 Whitehorse Lane
South Norwood
On 68A Bus Route
Nr.Thornton Heath &
Selhurst Park SR Rail Stations

ALL MAIL & OFFICES
Open Mon-Fri 9.00-5:30
Dept WW. 32 Biggin Way
Upper Norwood
LONDON SE19 3XF

DISTEL © The Original FREE On line Database
Info on 1000's of items
V21,V22, V22 BIS
0181 679 1888

ALL ☎ ENQUIRIES
0181 679 4414
FAX 0181 679 1927

All prices for UK Mainland. UK customers add 17.5% VAT to TOTAL order amount. Minimum order £10. Bona Fide account orders accepted from Government, Schools, Universities and Local Authorities - minimum account order £50. Cheques over £100 are subject to 10 working days clearance. Carriage charges (A)=£3.00, (A1)=£4.00, (B)=£5.50, (C)=£8.50, (D)=£12.00, (E)=£15.00, (F)=£18.00, (G)=CALL. Allow approx 6 days for shipping - faster CALL. Scotland surcharge CALL. All goods supplied to our Standard Conditions of Sale and unless stated guaranteed for 90 days. All guarantees on a return to base basis. All rights reserved to change prices / specifications without prior notice. Orders subject to stock. Discounts for volume. Top CASH prices paid for surplus goods. All trademarks etc acknowledged. © Display Electronics 1995. E & O E. 1/11

CIRCLE NO. 107 ON REPLY CARD

Intelligent agents under development

Researchers at BT's Martlesham laboratories in Suffolk are leading the world in the development of intelligent agents for use in tomorrow's 'super highway'. These agents could take on everything from organising the cheapest route for a long distance phone call to buying a car.

Part of the motivation for developing intelligent agents is the fear that dealing with the sheer volume and complexity of services available on the superhighway will be too complicated for most human beings. Intelligent agents will act as friendly intermediaries between us and the network allowing us to interact with the network in a natural way.

Software used in BT's intelligent agents differs from ordinary pieces of code in two key ways. It is not a set of detailed instructions on how to respond to every situation, but a general description of the way the agents should behave. They mimic the way humans behave, working by trial and error rather than planning in detail. Secondly, the software can learn from experience and adapt the way it behaves to perform better.

Although BT is keeping the details of how its intelligent agents are programmed to behave and learn a closely guarded secret, Dr Chris Winter, project leader for its intelligent agent programme, says the techniques are borrowed from work on neural networks and game theory.

BT believes an early application of intelligent agents could be to plot the cheapest routes for telephone calls. Winter's group has already demonstrated intelligent agents performing this function. The call could be routed through several different networks representing the cheapest path to its final destination. Rates could be negotiated based on knowledge of the current costs and demand for bandwidth on the networks.

BT is not the only company working on intelligent agents. Other major telecoms firms such as Northern Telecom and AT&T are running similar programmes, although BT believes it is leading the way in agents that can negotiate.

While BT's agents live on their 'master's' network terminal all the time, other companies are developing agents that are more mobile. "Our agents stay in one place at the moment and communicate across the network," Winter says, "but AT&T's agents actually move around the network, copying themselves". He is not yet convinced of the value of such roaming agents.

More important, in Winter's eyes, is to make the way we interact with agents more and more like the way we deal with other humans, with meaning conveyed through facial expression or hand motions.

Karl Schneider, *Electronics Weekly*

£25m R&D project

British semiconductor equipment companies are poised to participate with other European firms in the largest single microelectronics R&D project to date, funded by the EU's £10bn Fourth Framework Programme. If accepted, the proposal, worth £25m will examine ways of extending photolithography technology beyond the visible light spectrum, including the possible use of X-rays. Potential UK participants include Rutherford Laboratories, Lumonics and Leica Cambridge. The project is being jointly funded by the EC and Jessi, the pan-European collaborative microelectronics venture.

World's smallest power amp for mobile comms systems

Toshiba has developed what it claims to be the world's smallest power amplifier module. The amplifier is aimed at the digital mobile communications systems currently under development and is approximately one third the size of current power amplifier modules, at 5.5 × 5.5 × 2.0mm. It also operates at 2.7V, reducing demands on the battery.

The amplifier IC design has been simplified, making it relatively easy to mass produce. The drain offset self-alignment is simpler than that of other Mesfets.

Total assembly area is minimised through application of a land grid array (lga) structure that puts the thermal bumps and i/o on the underside of the module. This enables all of the i/o electrodes on the motherboard to be covered, and supports highly integrated packaging.

Peripheral components consist of six passive components with a size of 1 × 0.5 × 0.5mm.

MOD spending cuts will shake up industry

Britain's defence electronics exporters could lose out to foreign competitors as a result of government plans to reduce the funding of Ministry of Defence procurement activities by £6m. Defence electronics suppliers are lobbying the MoD to lift the threat, which is the result of rationalisation of its electronics components standards review body. The electronics standards arm of the Defence Research Agency (DRA) is due to have its role drastically reduced next March.

While accepting the need for cuts, the components industry is concerned that its competitiveness abroad will be jeopardised if the cost-cutting programime is mishandled. "It is vital that a common standard of quality-assessed component procurement is adopted – equipment makers and component companies both want that", said a spokesman for the Federation of the Electronics Industry.

At the centre of the row is the future of the DRA's electronics standards watchdog, known as the PCS. This oversees the MoD's priority and quality programme for the ordering of electronics components as laid out in DEFCON 17 document. The PCS, which accounts for almost half of the MoD's electronics standards budget, also ensures that the interests of UK suppliers are represented on international standards committees such as CECC and NATO's priority list, known as MUAHAG.

Removal from Mil Standard lists would threaten exports of UK suppliers. According to one industry source, 75 UK companies currently have components qualified for the internationally-recognised Mil Standard. "All these things could go into jeopardy," said the source.

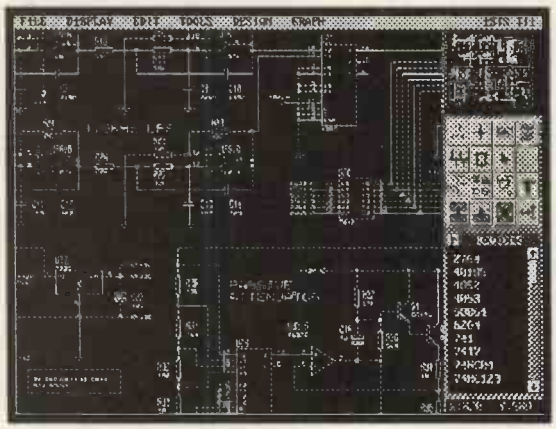
The government issued its plans for the PCS in a discussion document published in October. The scale of the hostility from industry has surprised the government, which has been forced to rethink its original proposal to close PCS in March with the loss of as many as fifty staff. "As I understand things, it is all back in the melting pot," commented a spokesman for the FEI.

One option being considered is replacing the out of date DEFCON 17 protocol with self-auditing of component quality by the suppliers. "You don't need the PCS to police industry with self-audit," said the FEI spokesman.

R. W.

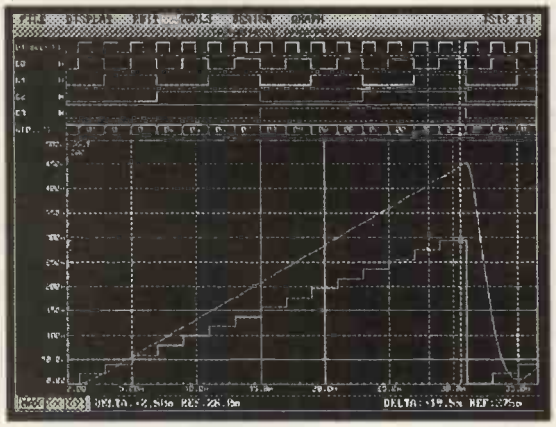
PROTEUS

The Complete Electronics Design System



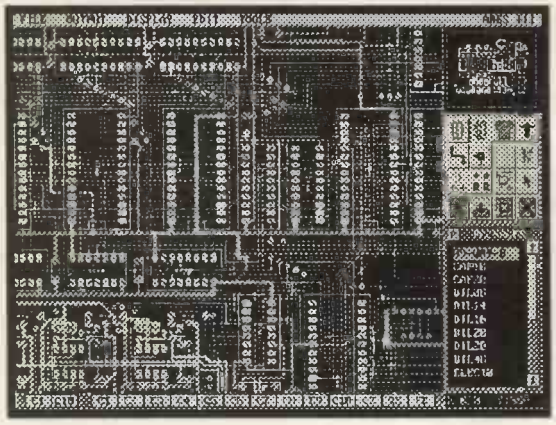
Schematic Capture

- Easy to Use Graphical Interface.
- Netlist, Parts List & ERC reports.
- Hierarchical Design.
- Extensive component/model libraries.
- Advanced Property Management.
- Seamless integration with simulation and PCB design.



Simulation

- SPICE compatible Analogue Simulation.
- Event driven Digital Simulation with modelling language & PLD support.
- Partitioned simulation of large designs with multiple analogue & digital sections.
- Graphs displayed directly on the schematic.



PCB Design

- Multi-Layer and SMT support.
- Unlimited Design Capacity.
- Full DRC and Connectivity Checking.
- Advanced Multi-Strategy Autorouting.
- Output to printers, plotters, Postscript, Gerber, DXF and DTP bitmaps.
- Gerber View and Import capability.

Labcenter Electronics

Write, phone or fax for your free demo disk, or ask about our full evaluation kit.
Tel: 0756 753440. Fax: 0756 752857.
53-55 Main St, Grassington. BD23 5AA.

Proteus software is for PC 386 compatibles and runs under MS-DOS. Prices start from £475 ex VAT; full system costs £1495. Call for information about our budget, educational & Windows products. All manufacturers' trademarks acknowledged.

CIRCLE NO. 108 ON REPLY CARD

War escalates on video cd format

Fifteen years ago, after the VHS, Beta and V2000 video wars, the electronic companies vowed they would never cripple themsleves again with a format battle. They remembered this when they launched cd, after agreeing in advance on a single system. Then they forgot their lesson and launched DCC and Mini Disc as rivals. So far both have paid the price.

Now the companies are making another mistake and lining up for a fresh format war over a new standard for High Density Video cd. This battle is even more dangerous because it will unsettle the trade and public who are currently being asked to support the one hour single density Vcd system which is just reaching the shops.

Two years ago Philips and Sony developed Video cd – a 12cm cd which stores an hour of movie or karaoke pictures of VHS quality. Video cds are just reaching the shops. The first public demonstration of HD-DVD, a high density digital video disc that needs a completely new player, was given recently.

Because DVD stores up to ten times more digital data, it can carry a full length feature movie, with widescreen pictures of quality that equals broadcast television and six tracks of stereo or multilingual sound. One disc can carry both original and expurgated versions of the same movie. DVD can work with a personal computer to deliver a multimedia mix of reference and games material. Philips and Sony say they hope the new technology "will become the basis of optical media for the coming multimedia era".

Because the potential rewards are so huge, Toshiba is promoting a rival system for 'the 21st century' which it claims the Hollywood movie studios support. The balance of power sits with Matsushita, maker of Panasonic equipment and the largest consumer electronics manufacturer in the world.

All today's cds, whether used for audio, video or multimedia, rely on a finely tuned optical system. A spiral track of microscopic pits is read by a finely focused laser beam. The pits are spaced by 1.6 micrometres, which is around one fiftieth the width of a human hair. The laser emits infra-red light, with wavelength of 780 nanometres. The single-sided disc can store around 650 megabytes of data which is read at a constant rate of around 1.5 million bits a second. This lets a single-sided disc store just over an hour of moving pictures which have been very heavily compressed to the MPEG-1 digital standard.

The new high density cd will use a laser which emits red light with a shorter wavelength: 635nm. This lets it focus into a tighter spot and thus read smaller pits in a half width spiral. This gives the disc a storage capacity of 3.7 gigabytes. The rate at which the bits are read also varies, between 1 and 10 million a seconds, depending on whether the picture contains moving detail or stationary objects.

Together, these tricks let the new disc store 135 minutes of pictures coded to the superior MPEG-2 standard. IBM, Apple, Compaq and Microsoft are already working with Philips and Sony to set a multimedia standard for using the new disc with a new generation of pcs.

In a surprise move Philips and Sony have worked with US optics company 3M to propose a future option. This will double the storage capacity to 7.4 gigabytes and 270 minutes of continuous movie playback. The double-high density disc is pressed with two spiral tracks instead of one, each at slightly different depths in the plastics material.

The effect is like writing different messages on both sides of a window pane. The laser focuses on one track for one play through the disc, and then re-focuses on the other track for a second play through.

Toshiba's proposed disc will use similarly small pits, but glue two separately pressed discs together, back to back. The laser reads one side of the disc first, then moves round to the other side of the disc and reads that to double overall playing time.

Philips and Sony say it will be difficult to mass-produce Toshiba's glued discs. Toshiba says it will be dificult to make and read the double layer single sided discs used by Philips and Sony.

The companies promoting HD-cd now have both to support the future high density market without destroying the fragile market for the existing single density systems – a tricky problem of their own making.

C&W commits to multimedia

Cable & Wireless says its purchase of a small stake in General Magic, the California-based multimedia technologies consortium, signals the company's commitment to developing multimedia services.

"We believe that the Telescript technology developed by General Magic will enable us to offer multimedia services to consumers and businesses alike," said Mike Harris, CEO of C&W Federal Development.

C&W was one of four new companies to take a stake in General Magic last week – the other three were Japanese electronics firms Mitsubishi, Oki Electric and Sanyo. Existing stakeholders include Apple, Northern Telecom, Matsushita, Philips, NTT, Fujitsu, Toshiba and Motorola.

VLSI goes for MPEG

VLSI Technology has acquired MPEG 1 and 2 video decompression design blocks for its Asic library through a licensing deal with two year-old Californian video compression start-up, Mediamatics.

VLSI, which has previously said that it would not offer a standalone MPEG decompression device, intends to use the technology in its cable and satellite tv set-top box chips.

Mediamatics uses a combination of software and hardware proessing for the MPEG 2 video decompression algorithm. The deal includes its MPEG 1 and 2 hardware decoder designs as well as a suite of design tools which will enable VLSI to implement the technology as functional blocks in its asic library.

Earlier this year VLSI acquired a stake in French data transmission specialist Comatlas, as part of its plan to introduce silicon for the set-top box market. It has recently introduced a QPSK satellite tv demodulator and forward error correction device jointly developed with Comatlas.

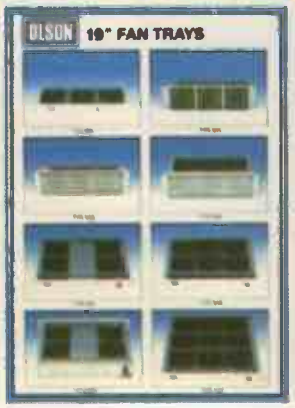
● Digital media compression specialist, Divicom, has selected LSI Logic's ATMizer architecture as the enabling technology for its digital broadcast system that will transport MPEG-2 compressed video streams over ATM. The MPEG-2 to ATM mapping scheme used in Divicom's encoder has been proposed to the ATM forum for adoption as the standard for MPEG-2 transport.

● C-Cube Microsystems has introduced chips for compressing video systems using MPEG-2, dramatically reducing the size of the encoder.

● Pioneer Electronic Europe nv has signed a contract with French DBS and pay tv company, Canal+, that will enable the company to offer digital broadcasting by the middle of this year. Panasonic will supply digital satellite receivers to Canal+ subscribers. It was selected as a supplier as the result of a competition launched in April 1994. ■

OLSON®

For all your Power Distribution Olson offer a varied choice



OLSON® ELECTRONICS LIMITED

FOUNTAYNE HOUSE, FOUNTAYNE RD., LONDON N15 4QL
TEL: 081-885 2884 FAX: 081-885 2496

CIRCLE NO. 138 ON REPLY CARD

RESEARCH NOTES

Jonathan Campbell

Helping hand cuts robots free – almost

Robots are still too stupid to be left to their own devices, while teleoperating them can be tedious for an operator. But the newest technique being hurriedly bolted-together in automation laboratories around the world is teleassistance, where a robot busies itself about its task, receiving only vital strategic information from its human master.

Teleassistance is quite different from the familiar teleoperation, where an operator remotely guides a robot to investigate a bomb, explore a volcano or even repair an orbiting space shuttle. Time delays can play havoc with sensitive control, and operators can end up feeling like their system is floating in treacle.

Obviously packing enough electrical intelligence into a robot so that it can act independently in complex situations is still science fiction rather than fact. But researchers, such as a team at the University of Rochester, are finding that a few simple hand signals from a human can dramatically increase both a robot's usefulness and independence.

Rochester graduate student Polly Pook, who recently presented her work at a conference on intelligent robots and systems in Germany explains:

"Any time you're dealing with an unknown environment, or with other people, the robot needs judgement and common sense – abilities that are extremely difficult to program".

In teleassistance, just a few strategic cues from a human operator – and a little programming – allow the robot to accomplish tasks autonomously, she says.

Pook describes today's robots as good at responding to local feedback, but still needing someone to provide context and set their agenda.

"In teleassistance, the robot has control over local problems like balancing and avoiding obstacles, and humans provide the goals and high level direction, such as where to go," says Pook.

He uses hand signals to communicate with the robot. The signals tell the robot what to do next, and sometimes, where or how to do it. The robot detects hand motions, through sensors mounted on a glove Pook wears.

"People frequently communicate with non-verbal signs," says Pook. "We point when giving directions, hold up a hand to mean stop and gesture to say come along. I can do the same with the robot".

So far, Pook has guided the robot in two tasks: opening a door and flipping a plastic fried egg. They may sound easy, but insignificant changes such as substituting a different door knob or spatula, or rearranging the positions of objects, can easily confound the robot.

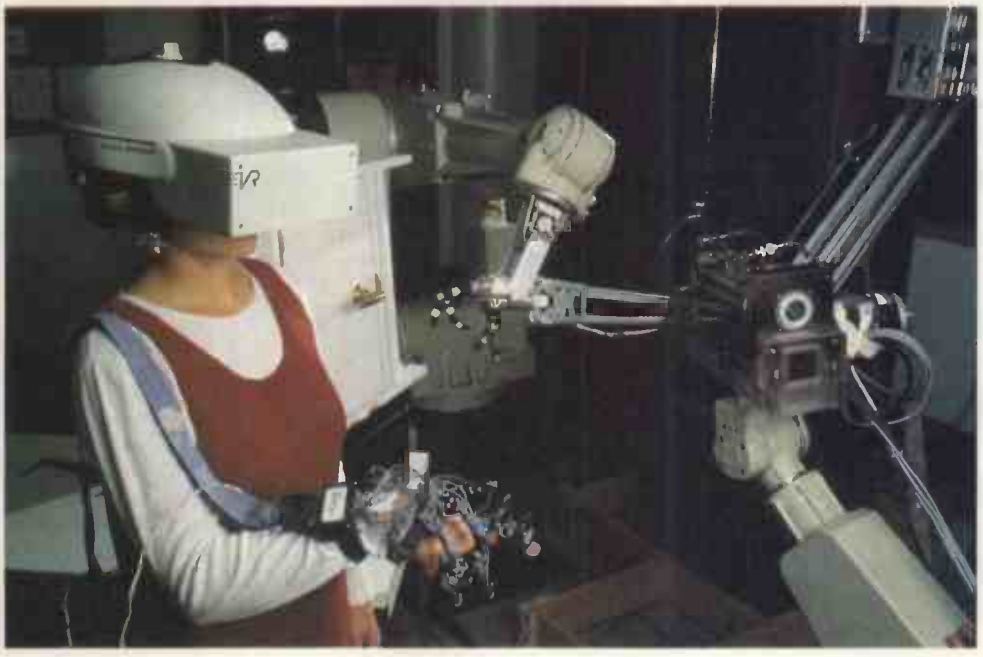
In the door-opening exercise, the robot reaches for the door after Pook points to it, and checks how Pook shapes her hand to discover the type of handle. Then the robot takes over using pre-defined programs to grasp and turn the handle and swing the door open.

In Pook's experiments, the tele-assisted robot opens the door much more reliably than an autonomous robot, while relying on just a fraction of the human effort compared to traditional teleoperation.

Within each context, it is able to respond quickly and appropriately to sensory feedback, without having to consider all possible world scenarios. "Once the robot knows its context, the behaviour flows smoothly and we can skip a lot of mathematics," says Pook.

Computationally-assisted telemanipulation is a science that is growing extremely fast. Pook recalls that when she began her work in teleassistance just a few years ago, hers was one of a handful of such presentations. But at the Iros conference, dozens of groups presented work in the area, with possible applications spanning robot assistance for the elderly and disabled, mining, exploration of remote sites and hazardous waste clean up.

Robots are not yet clever enough to be given a completely free hand. With Teleassistance, the robot has a great deal of autonomy, and the operator only needs to intervene with a few crucial commands.



Picture coutesy James Montanus/University of Rochester.

Submarine that swims like a fish

Scientists at Massachussetts Institute of Technology have moved one step closer to their goal of relating the physics of how a fish swims to development of an autonomous underwater vehicle. Following extensive testing of a 'robotuna' fish that swims up and down a tank, attached to a structure containing all its electronics, the MIT team has now started design of a more complex 'robopike', that will manoeuvre attached only by a tether.

David Barrett at MIT says that testing of robotuna has gone so well that the second model could be available this summer. The tether attachment should enable robopike to make hairpin turns, while accelerations of 10g are being targeted. A real fish could experience 25g.

The robofish project began about three years ago, prompted by the need for a better propulsion system for autonomous under-water vehicle (auvs). Small robotic submarine auvs could be used to map the ocean floor or find sources of underwater pollution. Unfortunately, conventional auvs can not carry enough batteries to allow them to explore areas such as the mid-Atlantic ridge. The obvious solutions are either to develop better batteries or improve the propulsion system. The MIT group has opted for the latter.

At present, the researchers are still concentrating on getting robotuna to swim as efficiently as possible in a straight line, to test whether their system is actually better. But other studies are also being carried out. For example, MIT is finding out more about the fundamental fluid mechanics of swimming. The robot is also acting as a test bed for possible controllers and sensors, and the researchers are using it to find a computer control system that will make a robot swim most effectively.

The project has involved a lot of watching, both real tuna at the New England Aquarium and the electronic robotuna. The mechanical fish has been built, as far as possible, to resemble a real one and its 2843 parts include over 40 ribs, a set of tendons, a segmented backbone with vertebrae, and a Lycra skin. The robot swims down the tank propelled by a tail that gently swishes back and forth as its flexible body follows suit.

MIT's robotuna could lead to a new method of propulsion for autonomous underwater vehicles.

Does electronics make us worse drivers?

As automobile manufacturers fight to pack ever more electronics into their cars, two studies recently carried out cast doubt on whether drivers can actually cope with any more technology.

The first concerns driver experience with relatively simple anti-lock braking (Allan Williams and Joanne Wells, *Accid. Anal. and Prev.*, Vol 26, No 6, pp.807-811).

In anti-lock systems, sensors monitor wheel rotational speed and as brakes are applied and the vehicle decelerates, a control unit determines when any wheel is about to lock up. If locking occurs, the control unit sends a signal to valves to reduce the brake pressure just enough to allow the wheel to start rotating again. The cycle is repeated until the driver's foot is removed from the brake or traction is restored. We all expect shorter stopping distance and improved stability should to be the result.

But data suggests that cars equipped with four-wheel anti-lock brake systems are no less likely to crash than those with conventional brakes.

Previous studies have suggested that one reason could be because drivers perform more aggressively and carry out more dangerous manoeuvres if they believe technology is going to come to their rescue.

In addition, Williams and Wells have found that many drivers simply do not know how to use anti-lock systems in an emergency. The most effective way to activate anti-lock systems is to brake hard and keep the foot down on the pedal – the opposite of how people are taught to avoid skids using conventional brakes. In the Williams and Wells work in the US, 33-50% of drivers of cars fitted with anti-lock systems said they would pump the brakes in a skid, negating much of the anti-lock effect.

In a second unrelated but relevant study appearing in the same journal (pp. 703-717), Nicholas Ward and Andrew Parkes from Loughborough University have been investigating head-up displays (huds), now beginning to find their way into cars.

Huds have obvious advantages. Information can be displayed in a driver's field of view, eliminating the need to shift the gaze from the outside world, and the proliferation of intelligent vehicle systems such as collision avoidance, route navigation and vision enhancement systems would seem to make them ideal display units.

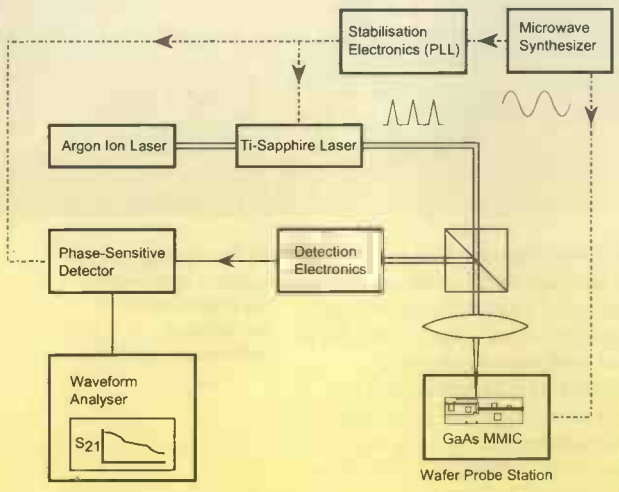
But the main objective of the hud has to be an increase in safety of vehicle operation. Unfortunately, much of the understanding of how huds are used comes from aeronautical applications, and the requirements of driving a car along a road are quite different. For example, background complexity adversely affects target visibility – and complex backgrounds are certainly a normal feature of every-day motoring. Studies suggest too that for some people, the hud may be much less effective than traditional head-down displays. Effects on speed and distance judgement could also have serious effect on safe traffic negotiation, and overall the safety consequences of such changes in attentional behaviour and information processing are not clear.

Their results convince the researchers that the hud should not be seen as just another display opportunity.

Taken with the findings on anti-lock brakes, a worrying conclusion seems to be that without very careful thought, electronics designed to make motoring safer could actually be making the roads a lot more dangerous.

Testing time for microwave circuits

NPL in the UK, the Fraunhofer Institute for Applied Solid State Physics in Germany and Dassault Electronique, France, have joined forces to develop an electro-optic probe station for measurement of rf and microwave integrated circuits to 20GHz and beyond.



Electro-optic probe station for GaAs microwave integrated circuit measurement.

Researchers at NPL investigating electro-optic sampling for measurement of fast electrical pulses and microwave signals. NPL has joined with the Fraunhofer Institute and Dassault to develop a useable test technique.

Demand for increasingly dense components, where it is difficult to lay down test points, are pushing current test techniques to their limits. But the NPL/Fraunhofer/Dassault work, sponsored by the European Commission, should improve circuit measurement capabilities by extending existing wafer-probe techniques.

Recent advances in the fields of electronics and opto-electronics have had a significant impact on communications, information systems and military markets. This has led to development of components and systems with bandwidths of many tens of gigahertz, capable of handling optical or electrical pulses and transients in the pico to nanosecond range. Electro-optic probing could become an important tool in the validation of new microwave integrated circuit designs.

As its name implies, the probe station will operate by using the electro-optic effect to sense microwave electrical fields at points inside an integrated circuit. The effect is exhibited by certain classes of non-centrosymmetric crystals which, in the presence of an applied electric field, acquire an induced anisotropic refractive index. Such materials are able to act as transducers for the detection of microwave signals by optical means, because the time-varying refractive index can be used to modulate an optical signal used in a probe. Change of phase of the optical signal can be related to the local microwave E-field strength in the circuit.

By scanning a sharply focused laser beam across a circuit, a high spatial resolution two-dimensional map of the field strength inside the circuit can be produced.

Two distinct techniques are possible for the electro-optic characterisation of microwave integrated circuits. Firstly, for III-V semiconductors which exhibit the electro-optic effect, such as GaAs, it is possible to use the phenomenon in the circuit substrate itself to sample the microwave field.

If the substrate is not electro-optically active – silicon or alumina for example – a small crystal of an electro-optically active material such as LiTiO mounted close to the circuit under test can be used as an external field probe.

The goal, according to Dr Alan Roddie of NPL, is a non-invasive technique that will be able to obtain results where conventional technology falls short. ■

PROGRAM 8 CHIPS IN THE TIME IT TAKES FOR ONE!

At £645 costing around half the price of slower gang programmers, the Speedmaster 8000 gang programmer uses a simple 2 button operation in stand-alone mode. PC operation gives comprehensive file handling and editing functions. Capable of gang and set programming it supports 32 pin EPROMs to 8M with no adaptors required. Programming cycle times of only 23 seconds for 8 27C010's mean your throughput can now be faster than ever before.

ROM/RAM EMULATOR PLUG IN CARDS

Using these expansion cards your programmer can run as if there's an EPROM or RAM plugged into the target socket. Available as 8 bit wide 128k x 8 as standard, upgradable to 512k x 8, and 16 bit capable of emulating 40 pin EPROMs. They can emulate both 5V and 3.3V devices.

PACKAGE ADAPTORS

A full range of package adaptors is available for non DIL devices and parts with more than 40 pins. Prices from £65.

DISTRIBUTORS
BENELUX: +3255313737;
CYPRUS: 02485378;
DENMARK: 048141885;
FINLAND: 070039000;
FRANCE: 0139899622;
GERMANY: 060827421615;
GREECE: 0190201 15;
ITALY: 02457841;
JAPAN: 053865501;
NORWAY: 063840007;
SINGAPORE: 04831691;
SOUTH AFRICA: 011974121 1/1521;
SPAIN: 013270614
USA: Distributors required.

FREE SOFTWARE UPGRADES! - KEEP UP TO DATE WITH NEW DEVICES

Before you choose your programmer, check out the cost of ownership. While other manufacturers charge for every update or require expensive libraries and modules, ICE Technology programmers support the whole range of devices at no extra charge*. And keeping up to date is FREE for life at no charge on our BBS service.
Just dial on: +44(0) 1226761181, and download the latest version.

Disk based upgrades are available free in the first year, and a small administration charge made for each subsequent disk.
* for DIL up to 40 pins.

AT LAST, AN AFFORDABLE 3V AND 5V UNIVERSAL PROGRAMMER!

The latest universal programmers from ICE Technology, the Micromaster LV and Speedmaster LV, now support programming *and* verification of 3.3V devices, now you can test devices at their actual operating voltage.

They offer wider device support than ever before, the majority requiring no adaptor. They will operate from battery or mains power, making them flexible enough whatever your programming needs.

Not only that, as new devices come onto the market we give free software upgrades and the units' modular design, with easy upgrade path, protects your investment.

Available now and priced from £495 they are everything you'll need for programming, chiptesting and ROM emulation.

FEATURES

- Widest ever device support including: EPROMs, EEPROMs, Flash, SPROMs, BPROMS, PALs, MACH, MAX, MAPL, PEELs, EPLDs Microcontrollers, etc.
- High speed, programmes a PIC16C54 in 0.5 secs (Micromaster LV).
- Up to 84 pin device support with adaptors.
- Connects directly to parallel port - no PC cards needed
- Built in chiptester for 7400, 4000, DRAM, SRAM.
- Lightweight and operates from mains or battery.
- Optional 8 or 16 bit wide ROM/RAM emulator.
- Designed, built and supported in the UK.
- FREE software device support upgrades via bulletin board.
- Next day delivery.

CIRCLE NO. 112 ON REPLY CARD

Speedmaster LV

Programmes 3 and 5V devices including memory, programmable logic and 8748/51 series micros. Complete with parallel port cable, software, recharger and documentation.

£495

MicromasterLV

As above plus support for over 90 different micro controllers without adaptors, including PICs, 89C51, 87C751, MC68HC705, ST6, Z86 etc.

£625

8 bit Emulator card

Expansion card containing 8 bit wide ROM RAM emulator, includes cable and software. 128K x 8.

£125

16 bit Emulator card

Expansion card containing 16 bit wide ROM RAM emulator, includes cable and software. 128K x 16.

£195

Call now to place your order, for more details or a free demo disk, or call our bulletin board to download the latest demo. Alternatively clip the coupon or circle the reply number.

Name: .....
Position: .....
Company: .....
Address: .....
.....
.....
Tel: .....
Fax: .....
EWW FEB

All major credit cards accepted

MasterCard VISA AMERICAN EXPRESS

ICE Technology Ltd. Penistone Court, Station Buildings, Penistone, South Yorkshire, S30 6HG, UK.
Tel +44(0)1226767404, Fax +44(0)1226370434, BBS +44(0) 1226 761181

With BT announcing extensive video-on-demand trials in the middle of this year, interest in the technology needed to control television pictures via the telephone is high. ***Geoff Lewis*** *believes that the technology in question – adsl – could even become a world-wide standard.*

ADSL

an easy route to video on demand

In the UK, legislation currently banning British Telecom (BT) from carrying broadcast tv signals over its telephone network, does not preclude the provision of a video-on-demand, or VOD, service. With suitable technology, this large installed subscriber network of more than 30 million twisted pair cables between local exchanges and domestic subscribers, means that BT is well placed to be able to provide a VOD service, in a relatively short space of time and at low cost. The telecommunication companies should thus be able to surmount the typical £200 consumer barrier for a system upgrade. Furthermore, such a system might well be extendable to support talking books for the blind, educational needs for open colleges, and the exchange of medical X-ray and various scan information for the Health Service. One assymetrical digital subcriber loop software vendor is already thinking of introducing interactive video games for multiple players, each competing with the others for some particular goal.

The unshielded twisted pair cables that were originally designed to provide analogue voice services in the frequency range 300 to 3400Hz, use copper or aluminium wires in various gauges, ranging from 0.32 to 0.9mm

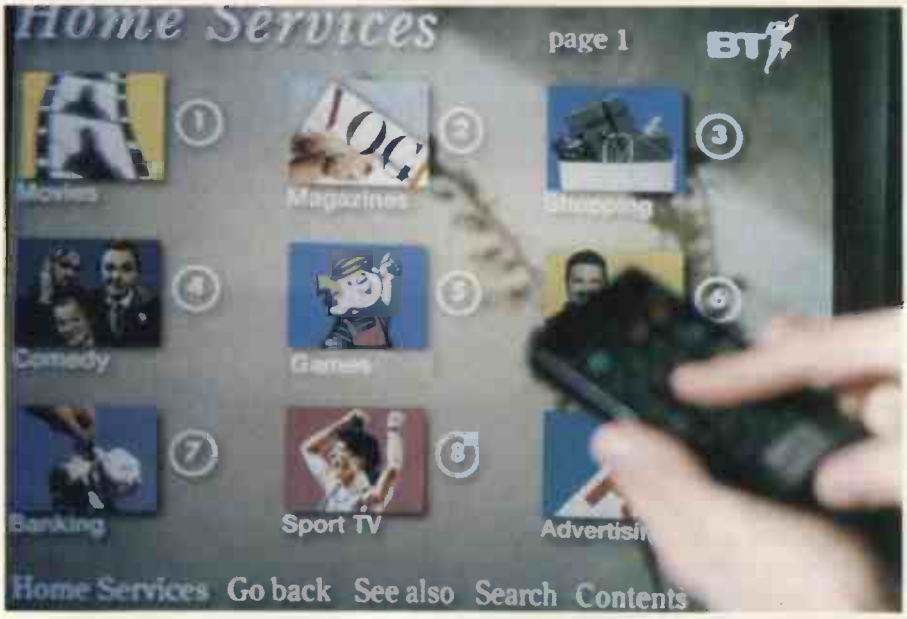
Who needs adsl?

Before a new technology becomes acceptable, the general public has to accept that it provides a solution to a recognised problem at an acceptable add-on cost. This can be seen by comparing the adoption rates of satellite and cable delivered television programmes with the rapid up-take of video recorders.

After the standards battle had been settled, with plenty of software available, the video recorder quickly became part of the entertainment system. First the recorder was used as a time shifting device to combat channel conflicts, then as a primitive form of video on demand, VOD, following the introduction of the local video shop.

If offered a more immediate form of video on demand, removing the need for the journey to the shop, the viewer would be presented with a solution to a problem that had probably not been previously recognised. Adsl promises to meet this need – and at a competitive price.

Although adsl is a product of the 1990s, internationally there are many players investigating its possibilities. Every month a new one joins the band of would-be service providers. Among the latest is Australia, where their sub-continental super-highway includes plans to incorporate adsl as a way of providing new services for areas of low population density.



Video on demand gives customers the sort of control over selected programmes and services that they would normally have on a video recorder – play, fast forward, rewind and freeze frame.

in diameter. Since any particular subscriber's final link may consist of a combination of these, the line attenuation may well vary from link to link.

About five years ago, it was recognised that unshielded twisted pair cables were in use with local area networks, lans, and carrying digital data at rates greater than 10Mbit/s. Research work in the USA at Bell Laboratories and in the UK at British Telecom then took a new look at the rf characteristics of the local loop. **Figure 1** indicates how the line attenuation and group delay varies for a typical section of unshielded twisted pairs up to 1MHz.

While attenuation over the major part of the range is high at about –0.075dB/kHz, the characteristic is fairly linear and easily equalised. But most importantly, the group delay is practically constant so that any pulse distortion will be small, with consequently few bit errors in a digital transmission. These features allow the simultaneous transmission of high bit rate digital signals and conventional telephony over the same local loop.

Figure 2 shows the general allocation of the frequency spectrum above the voice band. A low bit rate control channel operating at either 9.6, 16 or 64kbit/s provides for the subscribers' demands, together with a high bit rate channel for the delivery of selected tv and other programmes. It is this asymmetrical bit-rate allocation that gives the system its title of asymmetrical digital subscriber loop or adsl.

Organising the system in this way is cost effective. The hardware costs for the individual user end is relatively low, while the high costs of the high bit rate end are shared by many subscribers. Adsl can provide video with video-recorder type characteristics – fast forward, fast rewind, freeze frame, pause, etc functions – on demand.

Using MPEG-1 digital compression with suitable channel coding, video signals of various grades can be transmitted direct to the home. A bit rate of 2.048Mbit/s can provide VHS quality video together with digitally coded stereo sound. At 6.144Mbit/s with MPEG-2 compression, the video quality is equal to that of a broadcast transmission. The introduction of a new consumer-based demand would provide the necessary impetus to reduce the high cost of current MPEG-2 chip sets.

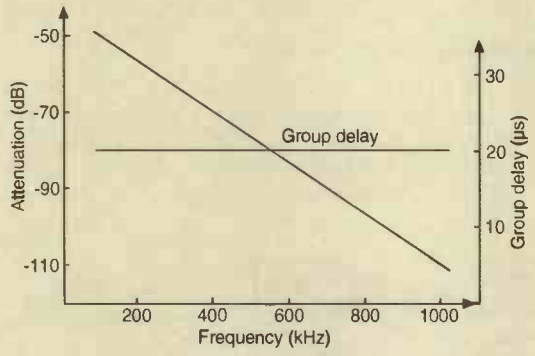


Fig. 1. Rf characteristics of unshielded twisted-pair telephone. While the attenuation might be anticipated, the constant group delay characteristic is fortuitous for a digital system.

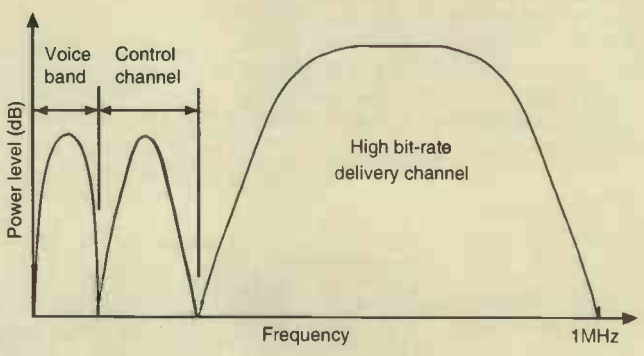


Fig. 2. Frequency-division multiplexing for adsl. This shows clearly adsl's ability to support simultaneous voice, telephony and the subscriber's demand and programme delivery channels.

There are various ways of allocating the high-bit-rate down-stream channel; four times 1.544Mbit/s and 6.176Mbit/s suit North America while three times 2.04Mbit/s and 6.144Mbit/s cater for Europe; other combinations are possible. Note that this makes the bit rates compatible with integrated-services digital network, isdn. As you would expect, the higher the bit rate systems, the shorter the local-loop penetration distance.

Analogue filters with high stop-band attenuation are used at each end of an adsl network in order to combine or separate the telephony and the extra services with the minimum of mutual interference. In practice, it is necessary to be able to separate adsl signals of a few millivolts in amplitude from a few tens of volts of ringing tone.

Because of the make-up of the local loop, many of which include overhead sections, there are many connections that can give rise to resistive variations which tend to be temperature and moisture dependant. In particular, overhead line vibrations and other variables can give rise to signal drop-outs that last for several milli-seconds. Adsl networks are designed not to reset under these conditions but to ride out such breaks.

Cross talk between the individual pairs in a multi-pair cable is not significant and neither is cross talk between other isdn users. Impulsive noise from ringing tones and switching signal could be troublesome, but by using a suitable transmission technique with forward error correction, fec, this has little significance in a well maintained network.

To minimise the effects of both radiated and induced radio frequency interference, adsl employs a balanced feed of signal to the line. By taking suitable preventative measures, adsl signals of less than 1mV amplitude can be recovered even under noisy conditions and in the presence of high level telephony signals. The specification includes forward error correction in the form of Reed-Soloman coding with the possibility of adding interleaving. Parameters for these features are incorporated in the American National Standards Institute (ANSI) documentation.

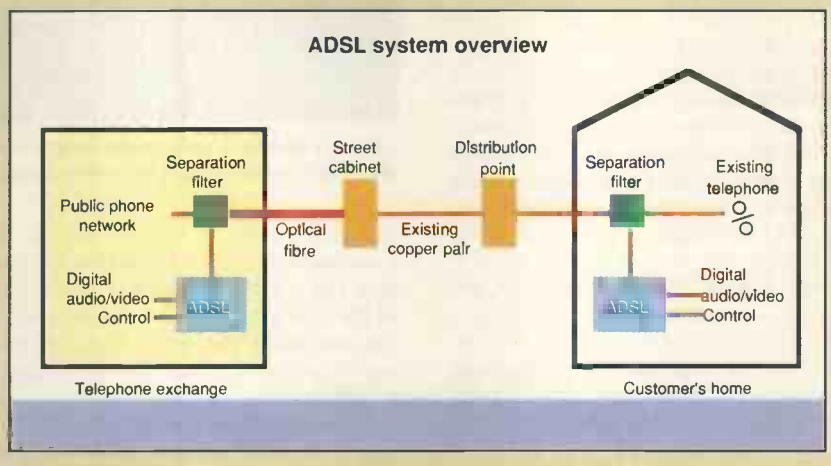
Digital adaptive equalisers adjust automatically to suit individual line characteristics. These cater for the problems including the temperature and moisture dependent parameters and continuous interference. Provision is made so that at each new line acquisition, the adaptive equalisers are reset under the control of a line-probing bit sequence that establishes the system signal-to-noise ratio. To maximise

Interactive tv trials

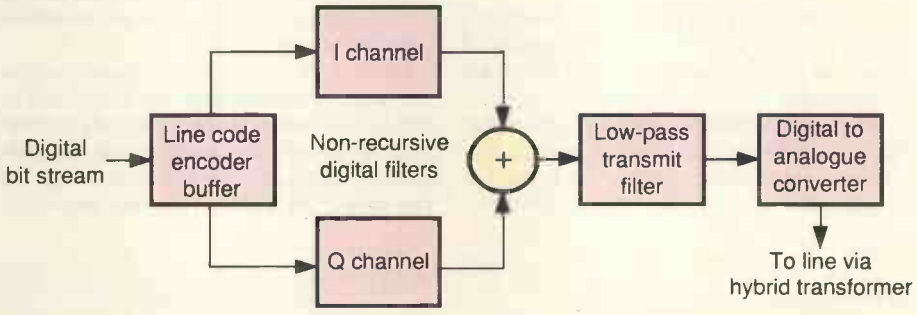
Towards the end of last year, BT announced that it is to start consumer trials of interactive tv – which includes video on demand. Starting in the middle of this year the trial is to involve 2500 households in Colchester and Ipswich. The move follows successful technical trials, held near Ipswich, involving sixty BT employees.

The new service will bring together the telephone and television to enable customers to choose from a range of services and material. Once selected in the home, video information is transmitted from a central database over the telephone network to the television, without affecting the normal telephone line.

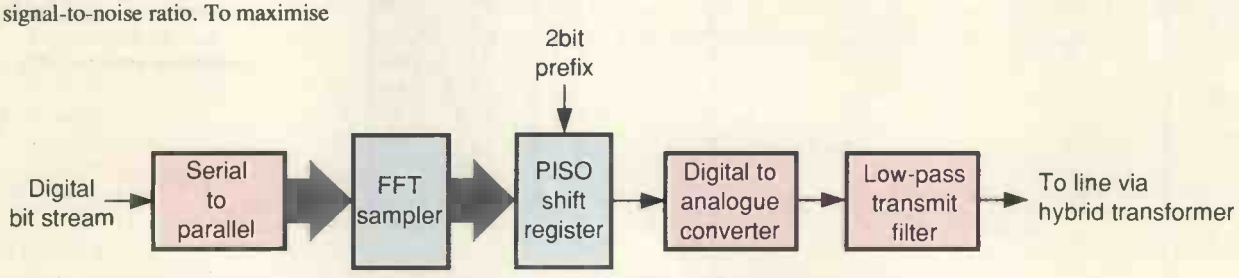
During the trial, BT aims to offer shopping on demand, a range of educational programming for homes and schools, movies and television programming (video on demand), a home banking service, a magazine service and a community link local information service.



Telephone television. With adsl, 16kbit/s data from the subscriber is used to access a one-way broadband video signal from the exchange.



The basic cap modulation system depends on relatively low cost, readily available vlsi chip sets.



Discrete multi-tone modulation system. While there is nothing new in the processors, vlsi device development for dmt is still at an early stage of development.

Video-on-demand technical trial results

Objectives of BT's technical trial were to test the feasibility of delivering video and multimedia services, with no market information objectives.

The set top box used was based on an Apple Macintosh *LC475* running a Mac operating system modified to support MPEG and a 2Mb/s network interface. At start-up it downloaded the operating system and Oracle Media Objects (OMOs), the run time version of the authorware tool in which the services are created.

The network connected to the set-top box was a 2Mbit/s stream delivered over either copper, using asymmetric digital subscriber loop (adsl), or fibre. Over an ordinary telephone loop, adsl technology delivers 2Mbit/s in one direction, a 9.6kbit/s bidirectional control channel, and the analogue telephone service.

The variety of adsl used in the trial was discrete multitone, which divides the spectrum into a number of bands and spreads the audio transmission over them in a such a way as to minimise interference and noise. For the fibre delivery a passive optical network was used.

Users were directly connected to the server system without any concentration or switching stage.The server system consists of an nCube massively parallel computer and the system ran on Oracle database software with the video content compressed to MPEG 1 standards.

Results of the trial were:

- Adsl technology is robust and has wider than expected range – of about 6km. Resistance to noise and to installation wiring anomalies is excellent, corresponding to 92% network penetration.
- The combination of MPEG coding and adsl works well. As a result, adsl is a viable technical solution to the problem of delivering high-bandwidth asymmetrical services.

BT will be using adsl for the market trial along with fibre in the ratio of about four copper to one fibre. In the technical trial discrete multitone was used, but carrierless amplitude and phase modulation adsl is to be used for the market trial. This is because it is available earlier in a more integrated and therefore cost effective form, says BT.

For the market trial, the same combination of server and set top box technologies supplied by nCube, Oracle and Apple Computers will also be used. However, there will be a switching/concentration stage which will be asynchronous transfer mode, atm, based. Users will be connected to an atm switch with a concentration ratio of roughly two to one. This means that there are about twice as many users as there are server ports, and about half of them can be on line to the system at any one time.

the channel capacity, bit rate reduction coding may be used. For example, with 2B1Q coding, each pair of binary input digits is converted into one of four quaternary output symbols.

Modulation format options

A number of different modulation formats have been tested and these include, qam, cap and dmt.

Quadrature amplitude modulation, qam. First, the binary data stream is split into two sub-streams and each separately modulated on to orthogonal versions of the same carrier frequency. The two modulated signals are then added and low pass filtered before transmission to network.

Carrierless amplitude-phase modulation, cap. The basic implementation of this technique is shown in **Fig. 3.** Again, the bit stream is split into two components. Each is then passed through a pair of Hilbert non-recursive digital filters that have an impulse response differing in phase by π. The outputs are then added, passed through a digital-to-analogue converter and filtered before being passed to the transmission network.

Discrete multi-tone modulation, dmt. This preferred method has a lot in common with cofdm, which is short for coded orthogonal frequency division multiplexing, in that the main channel is divided into many sub-channels.

Each serial digital input signal is first encoded into a parallel form and then passed through a fast-Fourier-transform processor. This converts the frequency domain samples into time domain values with a sliding time-window effect. These values are then transcoded into a serial format and digital to analogue converted before transmission.

Basic transmission processing is shown in **Fig. 4,** which shows that two or more prefix bits are added to the bit stream in order to minimise inter-block interference. When these bits are dropped in the decoder, the bit stream is typically broken up into 512 bit blocks to improve the definition of the FFT window. The line characteristic for each narrow sub-channel is practically constant so that the minimum of pulse smearing is created thus improving signal quality. Any impulse noise that appears as interference is spread over many sub-channels by the FFT processor window so this form of interference is less likely to create data errors.

Within a sub-channel, the number of bits transmitted can be varied adaptively depending on the signal to noise ratio in the sub-channel. This not only improves signal quality on a particular line, but it also minimises the effect of cross-talk from other lines.

While the dmt modulation scheme is more robust under noisy conditions, the processors are more expensive than those for cap modulation. However, at least one chip manufacturer has stated that chip sets could be available by the end of 1996 for under $100. Other proponents of adsl have variously estimated that if the take-up by subscribers is greater than about 10%, the system would be profitable to both chip set manufacturer and video-on-demand providers.

Whichever modulation scheme is used, the digital data is converted into analogue format, low pass filtered and coupled to the balanced line network via a hybrid transformer. In each case, the down-stream receiver functions in a complementary manner.

Hardware development is aimed at a single board approach with extensive use of standard vlsi chips wherever possible and with consumer prices very much in mind. The concept, which is a product of the 1990s, is compatible with the optical fibre networks that are currently in the process of being installed. When fibre is eventually installed in the final loop, both the quality of the images and the extent of the information services available in the home will be vastly expanded. Data rates in excess of 6.144Mbit/s have already been tested over relatively short voice-grade transmission lines.

Although the technology has been largely been driven by the laboratories such as BT and Bell, hardware manufacturers are starting to develop and offer systems to implement adsl. While BT is currently running trials in the UK, it is interesting to note that the telecoms organisations of Hong Kong, Korea and Singapore all plan to start trials before the end of 1994. With such Far Eastern interest, the costs of installing adsl must surely drop dramatically within the next three years.

Standards for adsl are currently being developed by ANSI by the working Group TIE1.4, under Document No TIE1.4-007 1993. The European Telecommunication Standard Institute (ETSI), group STC TM3 RG12, is currently engaged in agreeing the details of this annex. Since it is not expected that an independent European standard will develop and because of isdn compatibility, adsl could offer a possible world standard distribution system for television signals. ■

COMPUTER ICS

TMS 9900NL-40 PULLS ... £20 ea
S9900 NEW AMD EQUIVALENT ... £30 ea
TMS 9901NL-40 PULLS ... £20 ea
MC6802 PROCESSOR ... £2 ea
8742 1 SHOT ... £8 8742 WIPED ... £5
TMS320 ... £5 TMS320 1 SHOT ... £3
AM27C020-125L1 SURFACE MOUNT EPROM USED/WIPED ... £1.50
MM16450 UART CHIP ... £5 ea
P8271 BBC DISC CONTROLLER CHIP EX EQPT ... £25
SAA5050 TELETEXT CHIP EX EQPT ... £5
2817A-20 (2K×8) EEPROM ex eqpt ... £2
D41256C-15 256Kx1 PULLS ... 9 FOR £5
80C31 MICRO ... £2
P8749H MICRO ... £5
D8751-8 NEW ... £10
MK48Z02-20 ZERO POWER RAM EQUIV 6116LP ... £4
NEW 4164-15 ... £1
USED 41256-15 ... £1
USED 4164-15 ... 60p
BBC VIDEO ULA ... £10
8051 MICRO ... £1.25
8 × 4164 SIP MODULE NEW ... £8
FLOPPY DISC CONTROLLER CHIPS 1771 ... £16
FLOPPY DISC CONTROLLER CHIPS 1772 ... £17.50
68000-8 PROCESSOR NEW ... £6
HD6384-8 ... £5
ALL USED EPROMS ERASED AND BLANK CHECKED
2716-45 USED ... £2 100/£1
2732-45 USED ... £2 100/£1
2764-30 USED ... £2 100/£1.60
27C256-30 USED ... £2
27C512 USED ... £3.50
1702 EPROM EX EQPT ... £5
2114 EX EQPT 50p 4116 EX EQPT ... 70p
6264-15 8k STATIC RAM ... £2
GR281 NON VOLATILE RAM EQUIV 6116 ... £5
Z80A SIO-O ... £1.25
7126 3½ DIGIT LCD DRIVER CHIP ... £2 ea
2816A-30 HOUSE MARKED ... £2
USED TMS2532JL ... £2.50 2708 USED ... £2
HM6167LP-8 ... 65p
68000-10 PROCESSOR ... £6
8255-5 ... £1
2114 CMOS (RCA 5114) ... £1.60
M27C4001-12 USED/WIPED 4M EPROM ... £5
WD16C550-PC UART ... £9

REGULATORS

LM338K ... £6
LM323K 5V 3A PLASTIC ... £3
LM323K 5V 3A METAL ... £3
SANKEN STR451 USED IN AMSTRAD MONITORS ... £5
78H12ASC 12V 5A ... £5
LM317H T05 CAN ... £1
LM317T PLASTIC TO220 variable ... £1
LM317 METAL ... £2.20
7812 METAL 12V 1A ... £1
7805/12/15/24 ... 30p
7905/12/15/24 ... 30p
CA3085 TO99 variable reg ... 2/£1
78HGASC + 79HGASC REGULATORS ... £30 ea
LM123 ST93 5V 3A TO3 REGS ... £3 ea
UC3524AN SWITCHING REGULATOR IC ... 60p

CRYSTAL OSCILLATORS

2M4576 3M6864 5MO 5M76 6M144 7M000 7M3728 8M000 12M000 14M3181 17M6256 16M257 18M000 20M000 23M587 24M000 25M175 27M0 27M036 28M322 32M000 33M3330 35M4816 40M000 44M444 44M900 48M000 64M000 1M000 1M8432 4M000 10M000 16M000 18M432000 19M0500 20M0500 38M10000 56M6092 76M1 84M0 ... £1.50 ea

CRYSTALS

4M0256 10M368 17M6256 18M432 25M000 28M4694 31M4696 48M000 55M500 111M80 112M80 114M318 114M80 1M0 1M8432 2M000 2M4576 2M77 3M00 3M2768 3M579545 3M58564 3M93216 4M000 4M19304 4M433619 4M608 4M9152 5M000 5M0688 6M0000 6M400 8M000 8M488 9M8304 10M240 10M245 10M70000 11M000 12M000 13M000 13M270 14M000 14M381818 15M000 16M000 16M5888 17M000 20M000 21M300 21M855 22M1184 24M000 34M368 36M75625 36M76875 36M78125 36M79375 36M80625 36M81875 36M83125 36M84375 38M900 49M504 54M19166 54M7416 57M75833 60M000 69M545 69M550 BN 26M995 RD27M045 OR27M095 YW27M145 GN27M195 BL27M245 3M225 ... £1 ea

TRANSISTORS

MPSA92 ... 10/£1
2N2907A ... 10/£1
BC477, BC486 ... 10/£1
BC107 BCY70 PREFORMED LEADS full spec ... £1 £4/100 £30/1000
BC557, BC238C, BC308B ... £1/30 £3.50/100
2N3819 FETS short leads ... 4/£1
2N2907 PLASTIC CROPPED ... £1/15 £4/100

POWER TRANSISTORS

OC29 ... £1.35 ea
P POWER FET IRF9531 8A 60V ... 3/£1
N POWER FET IRF531 8A 60V ... 2/£1
2SC1520 sim BF259 ... 3/£1 100/£22
TIP 141/2 £1 ea TIP 112/42B ... 2/£1
SE9301 100V 1DA DARL SIM TIP121 ... 2/£1
PLASTIC 3055 OR 2955 equiv 50p ... 100/£35
BUZ31 POWER FET TO-220 200V 12 5A ... 2/£1

TEXTOOL ZIF SOCKETS

28 PIN USED ... £3 ... 40 PIN NEW ... £10
SINGLE IN LINE 32 WAY CAN BE GANGED FOR USE WITH ANY DUAL IN LINE DEVICES . . . COUPLING SUPPLIED ... 2/£1.50

NEW BITS

2 VOLT 920 A/hr LEAD ACID CELLS, UNUSED, UNFILLED 18" HIGH 12" × 7", WEIGHT 48Kg each, RUBBERISED CASE, GAULTLETED TUBULAR PLATE CONSTRUCTION, FOR DEEP CYCLE, HIGH CURRENT USE, MADE FOR BRITISH NAVY, 800 CELLS AVAILABLE, PHONE FOR PRICING ALSO AVAILABLE FILLED & CHARGED
Narrow angle infra red emitter LED55C ... 2/£1
UM6116M-2L surface mount 1000 available ... £1
Z80B PIO 7000 available £1 each, qty. price ... 30/50p
CNY65 OPTO ISOL 3000 available ... 50p
OPTO ICS also available TLP550 TLP666GF
68 way PLCC SKT 1500 available ... £1 each
100 wa PLCC SKT 100 available ... £1.50 each
1250pF POSTAGE STAMP COMPRESSION TRIMMER ... £1

MISCELLANEOUS

MINIATURE FERRITE MAGNETS 4x4x3mm ... 10/£1
ALPS MOTORISED DUAL 47K LOG pots with spindle, works on 6v-12v ... £1.50 ea
TL071 LO NOISE OP AMP ... 5 for £1
TL081 OP AMP ... 4 for £1
47000u 25v SPRAGUE 36D ... £3.50 (£2)
12 way dil sw ... £3 for £1
10NF 63V X7R PHILIPS SURFACE MOUNT 100K available ... £30/4000
SWITCHED MODE PSU 40 WATT UNCASED QTY. AVAILABLE +5v 5A, +12V 2A, 12V 500mA FLOATING ... £9.95 (£2)
220R 2.5W WIREWOUND RESISTOR 60K AVAILABLE ... £50/1000
CMOS 555 TIMERS ... 2/£1
2/3 AA LITHIUM cells as used in compact cameras ... 2/£1.50
ICM7126CPL CMOS 3½ DIGIT LCD DRIVER CHIP ... £2ea
LITHIUM CELL 1/2 AA SIZE ... 2 FOR £1
PASSIVE INFRA RED SENSOR CHIP + MIRROR + CIRCUIT ... £2 ea
EUROCARD 21-SLOT BACK PLANE 96/96-WAY ... £25 ea
"PROTONIC 24 VARIBUS" 16.7"×5" FIBREGLASS MULTILAYER PRH PCB - EUROCARD 96-WAY EXTENDER BOARD 290×100mm ... £10 ea
"PROTONIC 24" c/w 2 SUPPORT ARMS/EJECTORS. DIN 41612 96-WAY A/B/C SOCKET PCB RIGHT ANGLE ... £1.30
DIN 41612 96-WAY A/B/C SOCKET WIRE WRAP PINS ... £1.30
DIN 41612 64-WAY A/C SOCKET WIRE WRAP PINS ... £1
DIN 41612 64-WAY A/C PLUG PCB RIGHT ANGLE ... £1
DIN 41612 64-WAY A/B SOCKET WIRE WRAP (2-ROW BODY) ... £1
BT PLUG+LEAD ... 3/£1
MIN. TOGGLE SWITCH 1 POLE c/o PCB type ... 5/£1
LCD MODULE sim. LM018 but needs 150 to 250V AC for display 40×2 characters 182×35×13mm ... £10
6-32 UNC 5/16 POZI PAN SCREWS ... £1/100
NUTS ... £1.25/100
PUSH SWITCH CHANGEOVER ... 2/£1
RS232 SERIAL CABLE D25 WAY MALE CONNECTORS ... £5.90 ea (£1.30)
25 FEET LONG, 15 PINS WIRED BRAID + FOIL SCREENS ... INMAC LIST PRICE £30
AMERICAN 2/3 PIN CHASSIS SOCKET ... 2/£1
WIRE ENDED FUSES 0.25A ... 30/£1
NEW ULTRASONIC TRANSDUCERS 32kHz ... £2/pr
Also available 28 slot vari-bus backplane same size + Price ... NEW
POWERFUL SMALL CYLINDRICAL MAGNETS ... 3/£1
BNC 50OHM SCREENED CHASSIS SOCKET ... 2/£1
SMALL MICROWAVE DIODES AE1 OC1026A ... 2/£1
D.I.L. SWITCHES 10-WAY £1 8-WAY 80p 4/5/6-WAY ... 80p
180VOLT 1WATT ZENERS also 12V & 75V ... 20/£1
MIN GLASS NEONS ... 10/£1
RELAY 5V 2-pole changeover looks like RS 355-741 marked STC 47WBost ... £1 ea
MINIATURE CO-AX FREE PLUG RS 456-071 ... 2/£1
MINIATURE CO-AX PCB SKT RS 456-093 ... 2/£1
PCB WITH 2N2646 UNIJUNCTION WITH 12V 4-POLE RELAY ... £1
400 MEGOHM THICK FILM RESISTORS ... 4/£1
STRAIN GAUGES 40 ohm Foil type polyester backed balco grid alloy ... £1.50 ea 10+ £1
ELECTRET MICROPHONE INSERT ... 2/£1
Linear Hall effect IC Micro Switch no 613 SS4 sim RS 304-267 ... £2.50 100+ £1.50
HALL EFFECT IC UGS3040 + magnet ... £1
1 pole 12-way rotary switch ... 4/£1
AUDIO ICS LM380 LM386 ... £1 ea
555 TIMERS £1 741 OP AMP ... 6/£1
ZN414 AM RADIO CHIP ... 80p
COAX PLUGS nice ones ... 4/£1
COAX BACK TO BACK JOINERS ... 3/£1
INDUCTOR 20µH 1.5A ... 5/£1
1.25" PANEL FUSEHOLDERS ... 3/£1
CHROMED STEEL HINGES 14.5×1" OPEN ... £1 ea
12V 1.2W small w/e lamps fit most modern cars ... 10/£1
STEREO CASSETTE HEAD ... £2
MONO CASS. HEAD £1 ERASE HEAD ... 50p
THERMAL CUT OUTS 50 77 85 120°C ... £1 ea
THERMAL FUSES 220°C/121°C 240V 15A ... 5/£1
TRANSISTOR MOUNTING PADS TO-5/TO-18 ... £3/1000
TO-3 TRANSISTOR COVERS ... 10/£1
PCB PINS FIT 0.1" VERO ... 200/£1
TO-220 micas + bushes ... 10/50p 100/£2
TO-3 micas + bushes ... 15/£1
Large heat shrink sleeving pack ... £2
IEC chassis plug filter 10A ... £3
POTS SHORT SPINDLES 2K5 10K 25K 1M 2M5 ... 4/£1
40k U/S TRANSDUCERS EX-EQPT NO DATA ... £1/pr
LM335Z 10MV/degree C ... £1
LM234Z CONST. CURRENT I.C. ... £1
BNC TO 4MM BINDING POST SIM RS 455-961 ... £1
MIN PCB POWER RELAYS 10.5v COIL 6A CONTACTS 1 p ole c/o ... £1
BANDOLIERED COMPONENTS ASSORTED Rs, Cs, ZENERS ... £5/1000
LCD MODULE 16 CHAR. X 1 LINE (SIMILAR TO HITACHI LM10) ... £5
OPI1264A 10kV OPTO ISOLATOR ... £1.35 ea 100+ £1 ea
'LOVE STORY' CLOCKWORK MUSICAL BOX MECHANISM MADE BY SANKYO ... £1 ea
Telephone cable clips with hardened pins ... 500/£2
10,000uF 16V PCB TYPE 30mm DIAx31mm ... 2/£1
EC CHASSIS FUSED PLUG B-LEE L2728 ... 3/£1
2A CERAMIC FUSE 1.25" QB ... 10/£1
40 WAY IDC RIBBON CABLE 100 FOOT REEL ... £5+CARR
20mm PCB FUSEHOLDER ... 5/£1
IEC CHASSIS FUSED PLUG B-LEE L2728 ... 3/£1
ASTEC MODULATOR VIDEO + SOUND UM1287 ... £2.25
BARGRAPH DISPLAY 8 RED LEDS ... £1.50
NE567 PHASE LOCKED LOOP ... 2/£1
NE564 ... £1
P8749H USED WIPED ... £2

DIODES AND RECTIFIERS

A115M 3A 600V FAST RECOVERY DIODE ... 4/£1
1N5407 3A 1000V ... 8/£1
1N4148 ... 100/£1.50
1N4004 SD4 1A 300V ... 100/£3
1N5401 3A 100V ... 10/£1
BA158 1A 400V fast recovery ... 100/£3
BY254 800V 3A ... 8/£1
BY255 1300V 3A ... 6/£1
6A 100V SIMILAR MR751 ... 4/£1
1A 600V BRIDGE RECTIFIER ... 4/£1
4A 100V BRIDGE ... 3/£1
6A 100V BRIDGE ... 2/£1
10A 200V BRIDGE ... £1.50
25A 200 V BRIDGE £2 ... 10/£18
25A 400V BRIDGE £2.50 ... 10/£22
2KBP02 IN LINE 2A 200V BRIDGE REC ... 8/£1

SCRS

PULSE TRANSFORMERS 1:1+1 ... £1.25
TICV106D 800mA 400C SCR 3/£1 ... 100/£15
MEU21 PROG. UNIJUNCTION ... 3/£1

TRIACS ... DIACS 4/£1

NEC TRIAC ACO8F 8A 600V TO220 ... 5/£2 100/£30
TXAL225 8A 500V 5mA GATE ... 2/£1 100/£35
BTA 08-400 ISO TAB 400V 5mA GATE ... 90p
TRAL2230D 30A 400V ISOLATED STUD ... £5 ea
TRIAC 1A 800V TLC381T 16k AVAILABLE ... 5 FOR £1 £15/100

CONNECTORS

D25 IDC PLUG OR SOCKET ... £1
34-way card edge IDCCONNECTOR (disk drive type) ... £1.25
CENTRONICS 36 WAY IDC PLUG ... £2.50
CENTRONICS 36 WAY IDC SKT ... £4.00
BBC TO CENTRONICS PRINTER LEAD 1.5M ... £3
CENTRONICS 36 WAY PLUG SOLDER TYPE ... £4
USED CENTRONICS 36W PLUG+SKT ... £3
14 WAY IDC BLOCK HEADER SKT ... 5/£1

PHOTO DEVICES

HI BRIGHTNESS LEDS CQX24 RED ... 5/£1
SLOTTED OPTO-SWITCH OPCOA OPB815 ... £1.30
2N5777 ... 50p
TIL81 PHOTO TRANSISTOR ... £1
TIL38 INFRA RED LED ... 5/£1
4N25, OP12252 OPTO ISOLATOR ... 50p
PHOTO DIODE 50P ... 6/£2
MEL12 (PHOTO DARLINGTON BASE n/c) ... 50p
LED's RED 3 or 5mm 12/£1 ... 100/£6
LED's GREEN OR YELLOW 10/£1 ... 100/£6
FLASHING RED LED 5mm 50p ... 100/£40
HIGH SPEED MEDIUM AREA PHOTODIODE RS651-995 ... £10 ea

STC NTC BEAD THERMISTORS

G22 220R, G13 1K, G23 2K, G24 20K, G54 50K, G25 200K, RES 20°C DIRECTLY HEATED TYPE ... £1 ea
FS22BW NTC BEAD INSIDE END OF 1" GLASS PROBE RES 20°C 200R ... £1 ea
A13 DIRECTLY HEATED BEAD THERMISTOR 1k res. ideal for audio Wien Bridge Oscillator ... £2 ea

CERMET MULTI TURN PRESETS ¾"

10R 20R 100R 200R 250R 500R 2K 2K2 2K5 5K 10K 47K 50K 100K 200K 500K 2M ... 50p ea

IC SOCKETS

14/16/18/20/24/28/40-WAY DIL SKTS ... £1 per TUBE
8-WAY DIL SKITS ... £2 per TUBE
32-WAY TURNED PIN SKTS ... 3 for £1
SIMM SOCKET FOR 2×30-way SIMMS ... £1

POLYESTER/POLYCARB CAPS

330nF 10% 250V AC X2 RATED PHILIPS TYPE 330 ... £20/100
100n, 220n 63V 5mm ... 20/£1 100/£3
10n/15n/22n/33n/47n/66n 10mm rad ... 100/£3.50
100n 250V radial 10mm ... 100/£3
100n 600V Sprague axial 10/£1 ... 100/£6 (£1)
2µ2 160V rad 22mm, 2µ2 100V rad 15mm ... 100/£10
10n/33n/47n 250V AC x rated 15mm ... 10/£1
1µ 600V MIXED DIELECTRIC ... 50p ea
1µ0 100V rad 15mm, 1µ0 22mm rad ... 100/£6
0.22µ 250V AC X2 RATING ... 4/£1
0.22µ 900V ... 4/£1

RF BITS

SAW FILTERS SW662/SW661 PLESSEY SIGNAL TECHNOLOGY 379.5 MHZ ... £1.50 ea
FX3286 FERRITE RING ID 5mm OD 10mm ... 10 for £1
ASTEC UM1233 UHF VIDEO MODULATORS (NO SOUND) 1250 STOCK ... £1.50
MARCONI MICROWAVE DIODES TYPES DC2929, DC2962, DC4229F1/F2 ... £1 EA
XTAL FILTERS 21M4 55M0 ... £2 ea
ALL TRIMMERS ... 3 for 50p
VIOLET ... 5-105pF
YELLOW 5-65pF RED 10-110pF GREY 5-25pF
SMALL MULLARD 2 to 22pF ... 3 FOR 50p £10/100
TRANSISTORS 2N4427, 2N3866 ... 80p ea
CERAMIC FILTERS 4M5/6M/9M/10M7 ... 60p ea
FEED THRU' CERAMIC CAPS 1000pF ... 10/£1
SL610 ... £5
6 VOLT TELEDYNE RELAYS 2 POLE CHANGEOVER (BFY51 TRANSISTOR CAN SIZE) ... £2
2N2222 METAL ... 5/£1
P2N2222A PLASTIC ... 10/£1
2N2369A ... 5/£1
VN10KM ... 4/£1

PLESSEY ICS EX-STOCK

SL350G SL360G SL362C SL403D SL423A SL521B SL523C SL541B SL850C SL1021A SP8655 SP8719DG

MONOLITHIC CERAMIC CAPACITORS

10n 50V 2.5mm ... 100/£4.50
100n 50V 2.5mm or 5mm ... 100/£6
100n ax short leads ... 100/£3
100n ax long leads ... 100/£5
100n 50V dil package 0.3" rad ... 100/£8
1µF 50v 5mm ... £6/100

QUARTZ HALOGEN LAMPS

12V 50watt LAMP TYPE M312 ... £1 ea HOLDERS 60p ea
6V 50watt ... £1

KEYTRONICS

TEL. 01279-505543
FAX. 01279-757656
P O BOX 634
BISHOPS STORTFORD
HERTFORDSHIRE CM23 2RX

SEND £1 STAMPS FOR CURRENT IC+SEMI STOCK LIST – ALSO AVAILABLE ON 3½" FLOPPY DISK

MAIL ORDER ONLY

MIN. CASH ORDER £5.00. OFFICIAL ORDERS WELCOME
UNIVERSITIES/COLLEGES/SCHOOLS/GOVT. DEPARTMENTS
MIN. ACCOUNT ORDER £10.00
P&P AS SHOWN IN BRACKETS (HEAVY ITEMS) OTHERWISE 95p

ADD 17½% VAT TO TOTAL

ELECTRONIC COMPONENTS BOUGHT FOR CASH

Interfacing via the pc's printer port, this 16-channel data-capture subsystem with 12-bit resolution can be moved between machines without having to open the computer's lid. In addition to its analogue inputs, the subsystem also provides an eight-bit digital output port, as Pei An explains.

CATCHING DATA VIA LPT1

The present precision data acquisition system has a 16-channel analogue multiplexing facility and a 12bit a-to-d conversion accuracy. It incorporates an on-board digitally-controlled variable gain amplifier, offering gains of 10, 100 and 1000.

Input voltage is in the range from –5V to +5V with an accuracy of about 1μV. The conversion rate is 7Hz. In addition, the system has an 8-bit digital output port. This allows the device not only to read analogue signals into the computer, but also to send data out of the computer for controlling external equipment.

There are two main modules in the data logging system – an a-to-d conversion board and an interfacing card. The former deals with analogue signal multiplexing, amplifying and analogue-to-digital conversion; the interfacing card manages communication between the a-to-d board and the computer.

I have designed two versions of the interfacing cards. The first is intended for interfacing with the centronics port of the computer and the second for interfacing with the RS232 ports. Both cards incorporate an *8255* programmable peripheral interfacing (ppi) IC. This provides three programmable eight-bit i/o ports through which the a-to-d converter board is connected. In this article, only the design of the centronics i/o card is discussed.

The a-to-d board can be connected to any i/o ports, provided that two 8-bit outputs and one 8-bit input are available. A complete data logging system connected to a pc or a laptop computer is illustrated in **Fig. 1**.

The description of this system is divided into two parts. The first one concentrates on the works of the a-to-d conversion board and the second on the centronics i/o card.

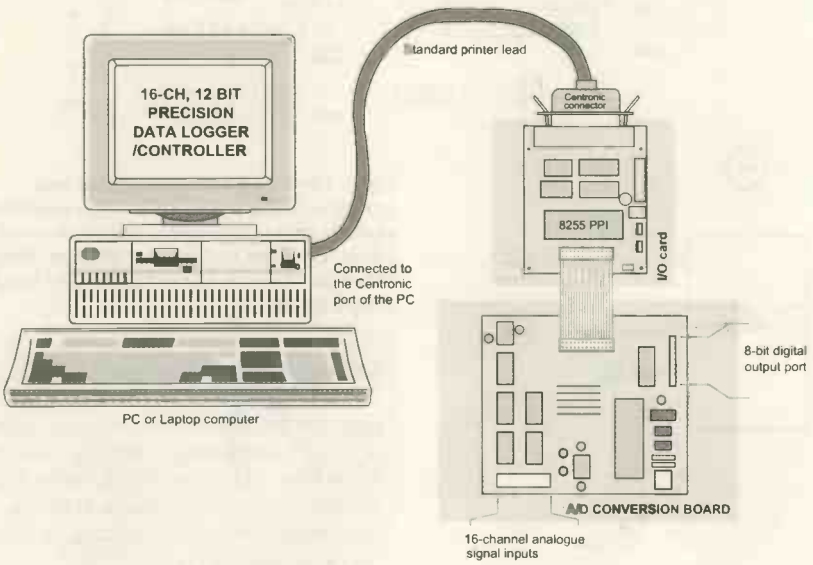
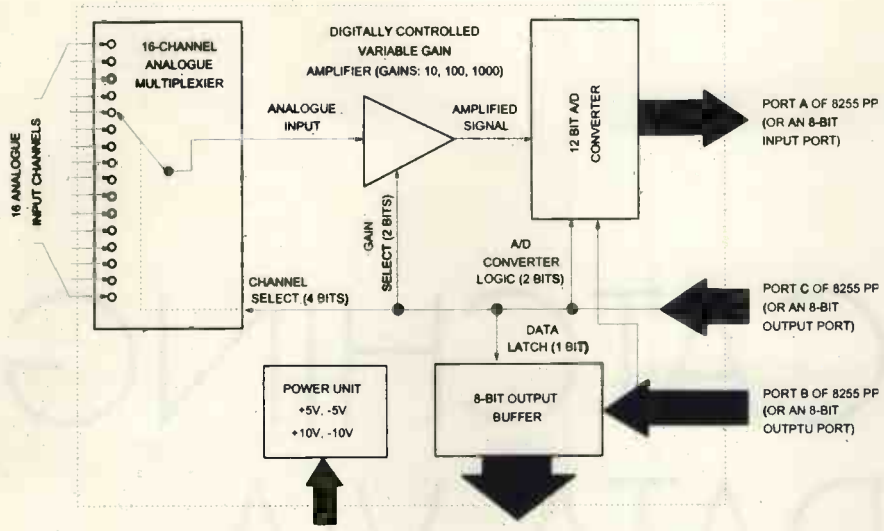


Fig. 1. Precision data logger/controller comprises an a-to-d converter board providing 16 analogue input lines and 8 ttl outputs. It is controlled by a pc or laptop computer via the centronics printer port using appropriate i/o card.

A-to-d conversion module

The system comprises five blocks. These are the analogue multiplexer unit, the digitally-controlled variable gain amplifier unit, the a-to-d conversion unit, the digital output unit and power supply unit. **Figure 2** shows the block diagram of the a-to-d board while **Fig. 3** gives the circuit diagram.

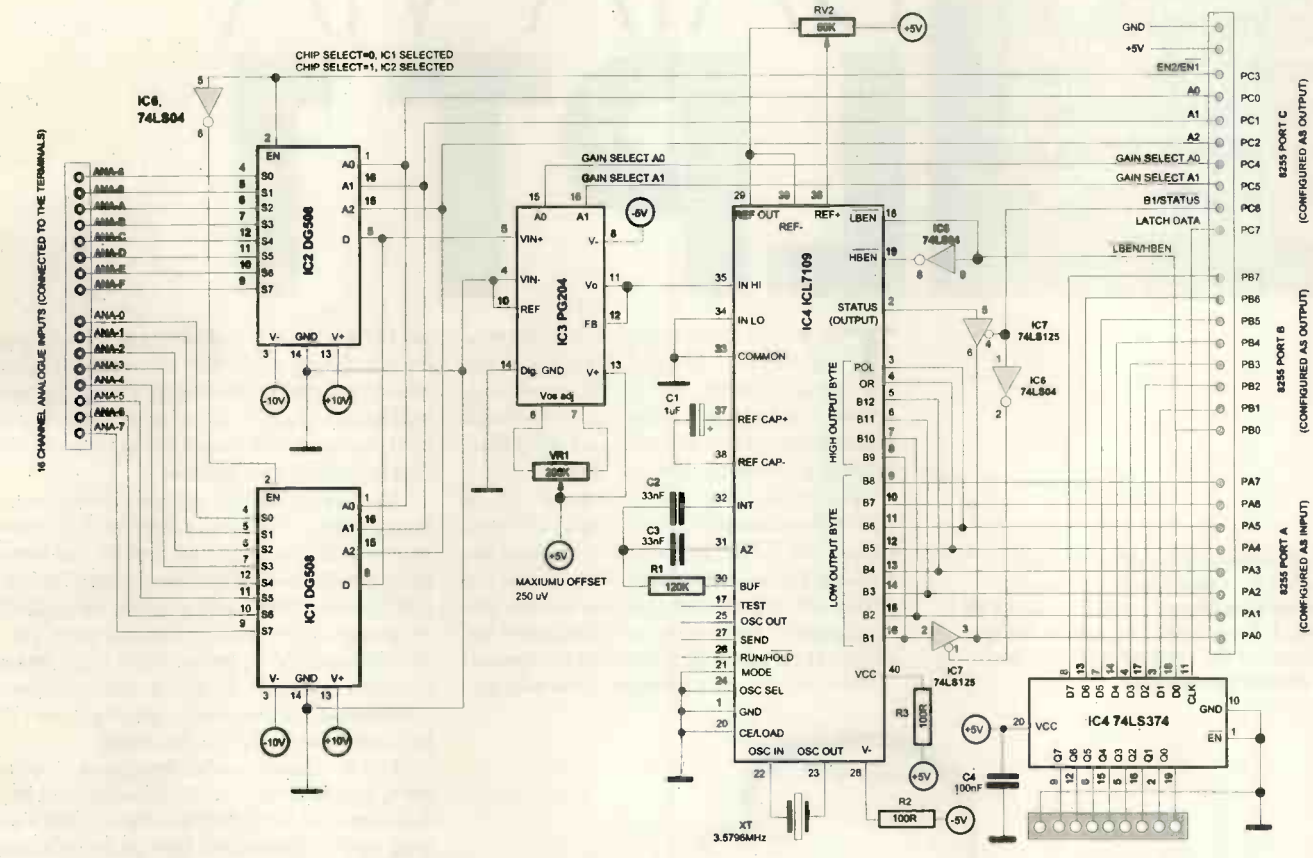
Analogue multiplexer. The analogue multi-



plexer unit is built around two *DG508* eight-channel analogue multiplexer ICs, namely $IC_{1,2}$. These provide 16 channels of analogue inputs.

The *508* is a high quality analogue switch exhibiting very low on resistance and high off resistance. On resistance is virtually constant over the entire analogue signal range. The IC can handle analogue input voltages up to ±40V. A dual balanced power supply is needed. Supplies V+ and V– connect to the +10V

Fig. 2. Block diagram of the a-to-d conversion board. One of the 16 analogue inputs is selected by the analogue multiplexer. The selected signal is first amplified by the digitally-controlled variable gain amplifier, then fed into the 12-bit a-to-d converter. Data from the computer is stored in the output buffers. The board communicates with the pc via one 8-bit input port and two 8-bit output ports.



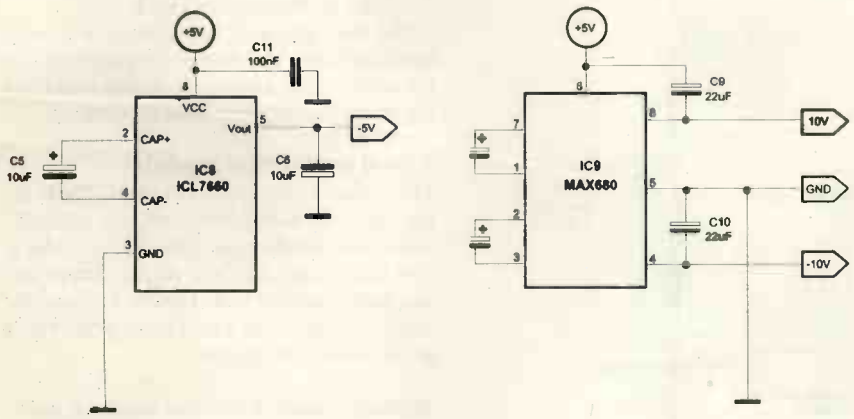


Fig. 3. The a-to-d board comprises two analogue multiplexers, a digitally-controlled variable gain instrument amplifier, a 12-bit a-to-d converter and support ttl chips. Output data from the pc is latched in the 374 octal D-type latches.

Software/hardware source

Printed-circuit boards, control software and parts for the a-to-d converter and centronics or RS232 interfacing cards are available from the author. For more details, write to Dr An at 58 Lamport Court, Lamport Close, Manchester M1 7EG, England, or phone or fax on +44-(0)161-272-8279.

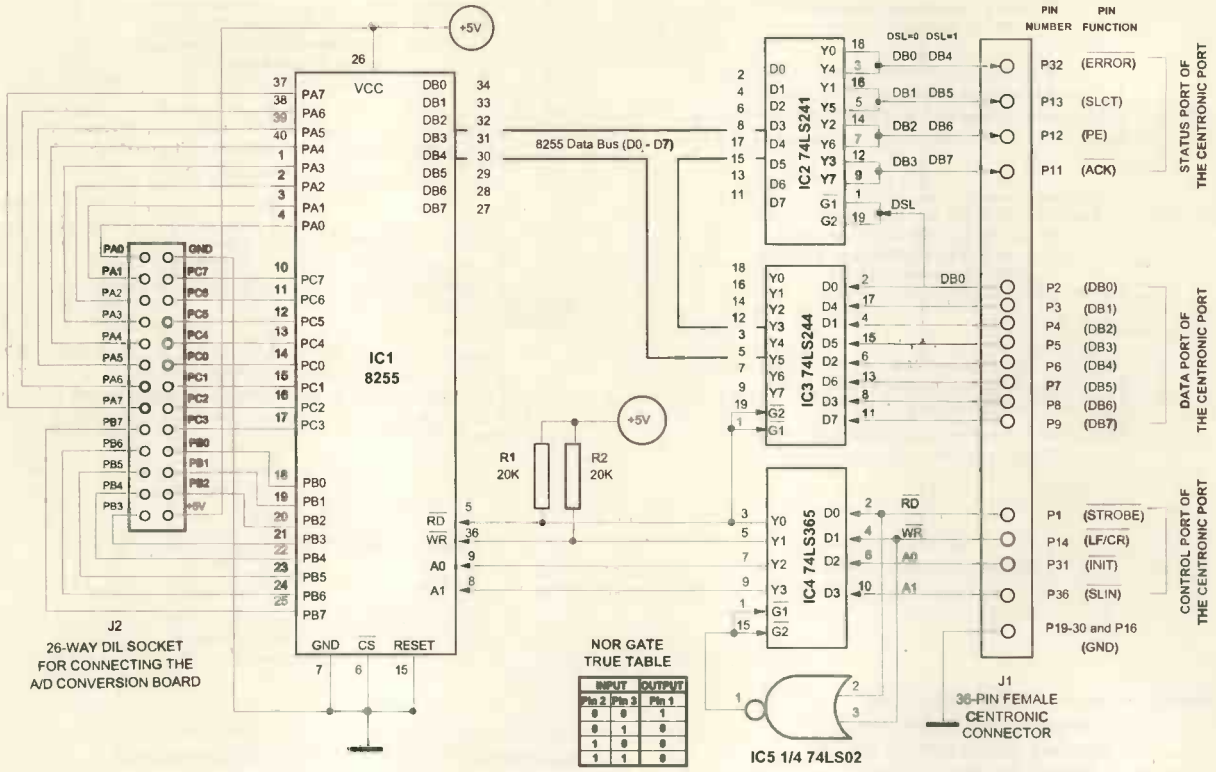


Fig. 4. Centronics port to 8255 peripheral interface chip. Communication between the computer and the 8255 is achieved by several ttl chips. Data and status ports centronics interface are used for sending data to and reading data from the 8255 peripheral IC. The control port manages operation of the 8255 peripheral chip.

and –10V rails of the power supply. Pins S_0 through S_7 are the analogue inputs while D, on pin 8, is the analogue output.

Analogue input is selected by applying an address at $A_{0\text{-}2}$ address lines. During the operation, the enable input should be pulled high. Address lines $A_{0\text{-}2}$ are connected to the lines $DB_{0\text{-}2}$ on port C of the *8255* peripheral IC. Enabling for IC_2 connects directly to DB_3 of port C and the enable for IC_1 connects to DB_3 via inverter IC_6. This ensures that only one multiplexer works at a time.

Analogue outputs of the ICs are wired together and then connected to the input of the amplifier, Fig. 3.

Variable-gain amplifier. Analogue outputs from the multiplexers connect to the input of the *PGA204* amplifier. This device is a high performance, low cost, general purpose instrumentation amplifier with programmable gain. It is laser trimmed for very low offset voltage and drift combined with high common-mode rejection. In addition, it will operate with supplies from 4.5 V to 18 V and its quiescent current is about 5mA.

Inputs *V+* and *V–* of the *PGA204* connect to the +5V and –5V rails of the power supply. Gains of 1, 10 100 and 1000 are digitally selected by two ttl/cmos-compatible address lines, $A_{0,1}$ on pins 15 and 16.

There is no latching for the address lines. A change in the address inputs immediately selects the new gain. However, a delay of around a microsecond is needed for the amplifier to settle to a new output voltage in the newly selected gain.

Input connects between V_{in-} and V_{in+}. Internal input protection allows overloads up to ±40V on the inputs without damage. Output V_o is referred to the output reference *REF*, which normally connects to the analogue ground via a low impedance.

The *PGA204* has an output feedback connection at pin 12 which must be connected to the V_o output terminal for proper operation. Normally, a constant current of approximately 1.3mA flows through the digital ground pin. This makes it necessary to return the digital ground through a separate connection path so that the analogue ground is not affected by current in the digital ground.

Pins 6 and 7 allow offset of the input stage to be trimmed. Address lines $A_{0,1}$ connect to $BD_{4,5}$ of the *8255*'s port C, which is configured as an output port.

A-to-d conversion unit. Amplified analogue signal is finally fed into the *ICL7109* 12-bit a-to-d converter. This IC is a high-performance, low-power, integrating a-to-d converter. It needs +5V and –5V power supplies on pins 40 and 28 respectively. Pin 1, *GND*, connects to the ground.

References REF_{IN+} and REF_{IN-} connect to a bandgap voltage reference. The *7109* provides an on-board voltage reference which is normally 2.8V below *V+* and has a typical temperature coefficient of ±80 ppm/°C. This reference voltage is at REF_{OUT}.

The IC needs some capacitors and resistors for the analogue side of the converter, values of which should be calculated according to the manufacturer's data sheet. An on-chip oscillator operates with an inexpensive 3.5795MHz tv crystal producing 7.5 conversions per second.

Digital communication with the *7109* is configured in direct mode, achieved by making the mode input pin open or low. In this mode, output data is directly accessible under control of the chip. The *RUN/HOLD* pin is unconnected and thus pulled high by the *7109*'s internal pull-up resistor. This allows the converter to perform a-to-d conversions continuously and to update the 14 tri-state outputs $B_{1\text{-}12}$, *OR* and *POL*. Lines $B_{1\text{-}12}$ present the 12 bits of the conversion data. Input over-ranging is indicated on the *OR* pin while *POL* indicates polarity of the signal.

During a conversion cycle, the status output goes high then low after new converted data has been stored in the output latches. It is used as a 'data-valid' flag for monitoring the status of the converter. In this design, *STATUS* and data bit B_1 share the same line, which connects to DB_0 of port A of the *8255* peripheral interface. Data line DB_6 of port B selects whether *STATUS* or B_1 is read into the pc.

Chip enable line *–CE/LOAD* connects to the ground to enable the IC. When *–LBEN* is low, the low eight bits $B_{1\text{-}8}$ output the data while high bits $B_{9\text{-}12}$, *OR* and *POL* are high impedance. When *–HBEN* is low, $B_{9\text{-}12}$, *OR* and *POL* will output data and the low bits are in high-impedance state.

In Fig. **3a**, some outputs in the two groups are connected together to form an eight-bit

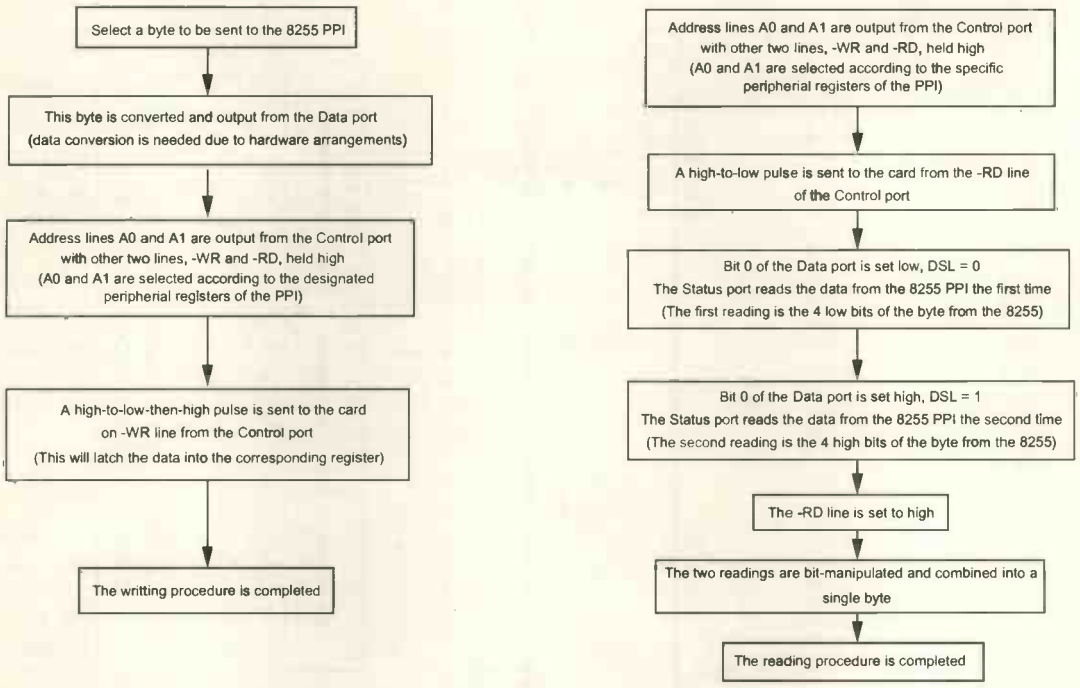


Fig. 5. Software flow for writing data to, and reading data from, the peripheral registers of the 8255 parallel interface. When writing, the data port of the centronics interface supplies data to the 8255 and the control port controls transfer. During reading, data from the 8255 is read into the pc via the status port. As only four inputs are used by the status port, the eight-bit data is loaded into the pc in two consecutive readings, which is controlled by the first lsb of the data port. Operation of the 8255 is again managed by the centronics control port.

output instead of 14 bits. Lines *–HBEN* and *–LBEN* are used to select the lines either in the high byte or in the low byte. These eight-bit data buses connect to port A of the *8255* peripheral interface which is configured as an input port. Line *–HBEN* connects to DB_0 of port B while *–LBEN* connects to DB_0 of port B via inverter IC_6.

Digital output unit. An *LS374* octal latch is used. Inputs to the IC are supplied by port B of the *8255*, which is configured as an output. This data is latched to the outputs by taking the clock line from low to high. The clock is connected to BD_7 of the *8255*'s port C.

Power unit. The power unit derives –5V and ±10V dc supplies from a 5V dc rail via two voltage conversion chips, Fig. **3b**. The *ICL7660* converts +5V to –5V while a *MAX680* converts +5V to +10V and –10V.

Interfacing to the pc

Interfacing via the centronics printer port was discussed in an article entitled '*Real world control via LPT*' in the September issue of *EW+WW*. Briefly, the centronics port consists of three independent ports, namely, the data

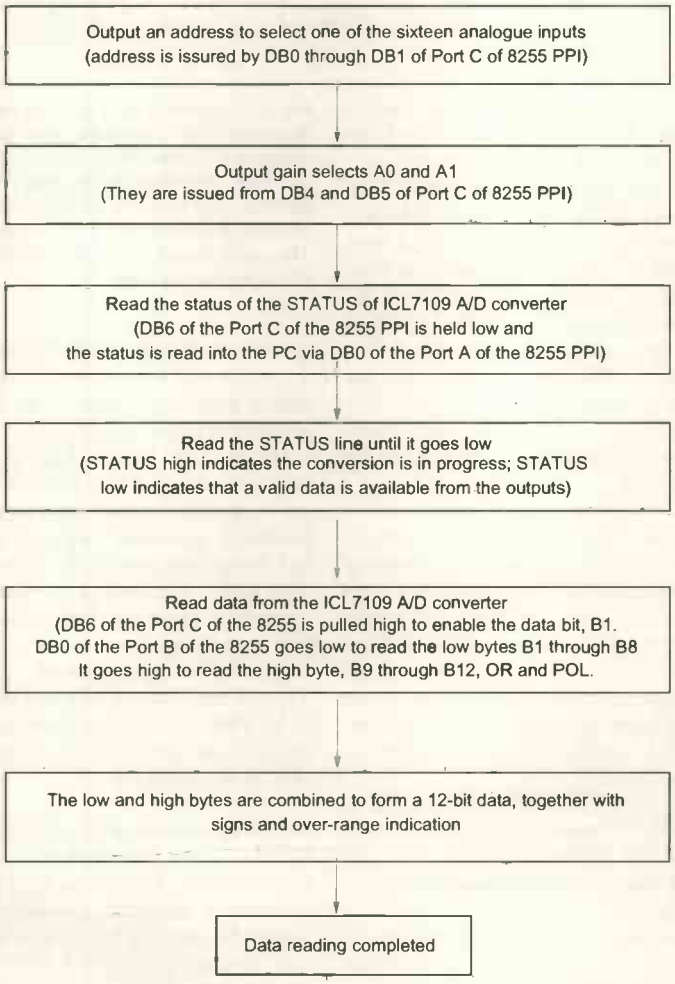


Fig. 6. Analogue-to-digital conversion begins with selecting one of the 16 analogue inputs. It is followed by sending a command to select the gain of the amplifier. After this the status of the a-to-d converter is polled continuously until it indicates that conversion is finished. The 12 bit data – plus polarity and over-range flags – are read into the pc twice. They are finally combined to form a single 12-bit word.

output port, the control output port and the status input port.

For the data logger, the centronics data port is used to send information to the interface card while the status port is used to read data from the IC. The control port manages reading and writing operations of the *8255* interface chip.

The *8255* is an industry standard programmable peripheral interface with four internal registers. Three of these are called peripheral registers and are associated with ports A, B and C. The fourth is the control register.

All three peripheral registers are used for data transactions between the *8255* and external circuits while the control register is used to initialise the operation modes of the parallel interface.

There are eight bidirectional data lines, $DB_{0\text{-}7}$, through which data is written to or read from the internal registers under the control of read and write lines. Address lines $A_{0,1}$ select a particular register.

Data transfer is facilitated by IC_2 and IC_3, which are tri-state buffers. Control over the *8255* is made by IC_4 and IC_5 which are a tri-stage buffer and nor gate respectively.

You can see from Fig. 4 that two lines of the centronics control port, pins 31 and 36, are connected to address lines $A_{0,1}$ of the *8255* peripheral interface via IC_4 – a tri-state buffer.

The other two lines of the control port, pins 1 and 14, connect to *–RD* and *–WR* of IC_1 via IC_4. A problem could occur when these two lines are both low, since the *8255 –RD* and *–WR* lines cannot be set low simultaneously. To prevent this, a nor gate is used. Its two inputs connect directly to the two control lines from the centronics port, pins 1 and 14, and its output connects to the enables of IC_4.

When the two lines from the control port are both low, output of the nor gate goes high. This disables the buffers on the *LS365* and sets all the outputs at high impedance. Resistors $R_{1,2}$ pull the *–RD* and *–WR* lines high.

To write data to an *8255* register, firstly the required data is written to the centronics data port together with an address to the control port, then a high-to-low-then-high pulse is issued from the control port write line. This enables data on the inputs of IC_3 buffers to be transferred to the *8255* data bus and in the same time written into the selected register.

Reading data from the *8255* is slightly complicated, since the centronics port only has five input lines. In order to read eight bits of data, the computer has to read at least twice. This is done by IC_2, an *LS241* tri-state octal buffer.

In Fig. 4, when the first enable, pin 1, is low, the four left hand side buffers work, i.e. the outputs follow the inputs. When pin 19, the second enable, goes high, the four right-hand side buffers operate.

By connecting pins 1 and 19 together to form a data-select line and by putting the line low and then high, the status port can read the four bits connected to the left and right hand buffers in turn. These two readings are then bit-manipulated and combined to form a single eight-bit byte.

Operating in such a manner, the 8-bit data appearing on the input lines of IC_1 can be read into the centronics port. Referring to Fig. 2, the data-select line is controlled by DB_0 of the centronics data port.

The card incorporates a *7085* 1A, 5V regulator. An external 8-12V dc supply capable of delivering about 100mA is needed. In my design, the regulated 5V supply also feeds the expansion socket for conveying power to the a-to-d conversion board. An 800mA on-board fuse is used.

Programming

I have written a control program in *Turbo Pascal 6* for this data logging system. Flow charts for the centronics i/o card and data logging system are shown in **Figs 5** and **6**. ■

KENWOOD

TEST & MEASURING INSTRUMENTS
A SUPERB RANGE OF OVER 100 QUALITY INSTRUMENTS.
Available from
B.K. ELECTRONICS

FM-AM Signal Generators ★ Colour Pattern Generators ★ Video Signal Analyser ★ Video Timing Analyser ★ Video Noise Meter ★ Distortion Meter ★ Waveform Monitors ★ Vectorscopes ★ Audio Generators ★ Wow and Flutter Meters ★ Electronic Voltmeters ★ Digital Multimeters ★ Function Generators ★ Frequency Counters ★ Bus Analyser ★ Resistance Attenuator ★ Oscilloscopes ★ Fully Programmable Digital Storage Oscilloscopes ★ Regulated D.C. Power Supplies

A free, 50 page colour brochure, including price list, is available on request. Please make your request on company headed notepaper, by post or by fax, to:

B.K. ELECTRONICS
Unit 1 Comet Way,
SOUTHEND-ON-SEA,
Essex, SS2 6TR.
Tel.: 0702-527572
Fax: 0702-420243

VISA

CIRCLE NO. 113 ON REPLY CARD

UNIVERSAL EASY-I.C.E. ™

See it
Evaluate it
Xtra Money

WE WILL PAY.... YOU

Just to view our NEW Low Cost Emulator....

EASY TO USE ..... Borland type IDE
UNIVERSAL ..... Supports most micros
LOW PRICE ..... Systems from £599

FAST... REAL-TIME Source Level debugging for any Assembler or 'C' Compiler

RING our NEW Sales Office
(BATH) 01225-448630

Flash Designs

CIRCLE NO. 114 ON REPLY CARD

M & B RADIO (LEEDS)

THE NORTH'S LEADING USED TEST EQUIPMENT DEALER

SPECTRUM ANALYSERS

HP3580A 5hz-50khz Audio spectrum analyser (as new) £1000
HP3581A 15hz-50khz Wave analyser £750
HP3581C 15hz-50khz Selective voltmeter £650
HP3582A 0.02hz-25.5khz Dual channel audio analyser £2500
HP8903A 20hz-100khz Audio analyser £3000
BOONTON 1120 20hz-100khz Audio analyser £3000
BRUEL & KJAER 2033 1hz-20khz £2250
TEXSCAN ALS1 4mhz-1000mhz Battery/mains portable analyser £750
TEKTRONIX 7L12 10khz-1800mhz Analyser/7000 mainframe £2500
HP8444A 500khz-1300mhz Tracking Generator £750
HP182T/8558B 10mhz-1500mhz Spectrum analyser £1800
HP140T/8552B/8553B 1khz-110mhz Spectrum analyser £450
HP141T/8552B/8553B+8443A Tracking generator/manuals (as new) £1000
HP141T/8552B/8554B 100khz-1250mhz+(8553B unit) £1000
HP141T/8552B/8555A 10mhz-18ghz + (8553B unit) £1700
FARNELL 352C 300khz-1000mhz Spectrum analyser £1350

SIGNAL GENERATORS

HP8616A 1.8ghz-4.5ghz Generator £195
HP8005B 0.3hz-20mhz Pulse generator £200
HP8007B 10hz-100mhz Pulse generator £250
HP8620C Sweeper mainframe (as new) £300
HP8620C/86290B 2ghz-18.6ghz Sweeper £2500
HP8018A Serial data generator £250
HP8406A Comb generator £275
HP3325A 1uhz-21mhz Synthesizer/function generator £1200
HP3336A 10hz-21mhz Synthesizer/level generator (75/124/135/600 ohm) £650
HP3336C 10hz-21mhz Synthesizer/level generator (50/75 ohm) £750
HP3586A 50hz-32.5mhz Selective level meter £1850
HP8683D 2.3ghz-13ghz OPT001/003 Solid state generator (as new) £4500
HP8672A 2ghz-18ghz Synthesized signal generator £6000
MARCONI TF2008 10khz-510mhz Generator/sweep £250
MARCONI TF2015/2171 10mhz-520mhz with synchronizer £325
MARCONI TF2015 10mhz-520mhz Generator £195
MARCONI TF2016 10khz-120mhz Generator £175
MARCONI TF2022E 100khz-1.01ghz Synthesized generator (new) £1850
MARCONI 6055 850mhz-2150 Signal source £150
GIGA GR1101A 12ghz-18ghz Pulse generator (as new) £650
POLARAD 1106ET 1.8ghz-4.6ghz with modulator £400
SAYROSA MA30 10hz-10khz Oscillator £150
ADRET 2230A 200hz-1mhz Synthesized source £200
LINSTEAD G1000 10hz-10mhz Synthesized oscillator £200
EXACT 502LC 1hz-5mhz Function generator £195
WAVETEK 182A 1hz-4mhz Function generator £195
FARNELL SSG2000 10khz-2ghz Synthesized generator (new) £2250

OSCILLOSCOPES

TEKTRONIX 2445A 150mhz 4 channel cursor readout (as new) £1550
TEKTRONIX 2445 150mhz 4 channel cursor readout £1300
TEKTRONIX 2215 60mhz 2 channel delayed sweep £400
TEKTRONIX SC504/TM503/DM501 80mhz scope/digital multimeter £450
TEKTRONIX 466 100mhz storage scope £395
TEKTRONIX 465 100mhz 2 channel delayed sweep £350
TEKTRONIX 7403/7A18/7A13/7B53A Scope £400
TEKTRONIX 7633/7A18/7A18/7B53A Storage Scope £500
TEKTRONIX 5113 Dual beam storage mainframe (new) £295
TEKTRONIX T922R 15mhz 2 channel rackmount scope £175
IWATSU SS5704 20mhz 2 channel scope £195
IWATSU SS6122 100mhz 4 channel cursor readout £895
HP 1722B 275mhz Delta time measurements £700
HP 1743A 100mhz Delta time measurements £500

HP 180 50mhz 2 channel scope £150
LEADER LBO524L 40mhz Delayed sweep £300
GOULD 5110 100mhz Intelligent scope £750
GOULD OS300 20mhz 2 channel scope £175
GOULD OS250B 15mhz 2 channel scope £100
PHILIPS PM3217 50mhz 2 channel delayed sweep £300
PHILIPS PM3217 50mhz With X1 X10 probes/manual (as new) £375
PHILIPS PM3244 50mhz 4 channel delayed sweep £450
PHILIPS PM3305 35mhz Digital storage scope £550

TEST EQUIPMENT

TEKTRONIX 1141/SPG11/TSG11 Pal generator £1750
TEKTRONIX 521A Pal vectorscopes £350
TEKTRONIX 6042 50mhz Current probe £225
TEKTRONIX P6015 High voltage scope probe £95
TEKTRONIX TM501/DM501 Bench multimeter £125
SYSTEMS VIDEO 2360 Component video generator £1500
PHILLIPS PM5507 Pal vectorscope £750
PHILLIPS PM5509 Pal TV pattern generator £295
PHILLIPS PM8252A Dual pen recorder £225
FLUKE 3330B Prog constant current/voltage calibrator £650
FLUKE 103A Frequency comparator £250
EXACT 334 Precision current calibrator £195
BALLANTINE 6125C Prog time/amplitude test set £400
HALCYON 500B/521A Universal test system £400
BRADLEY 192 Oscilloscope calibrator £600
AITECH 533X-11 Calibrator 1 HP355C/1 HP355D Attenuator inc £300
GAY MILANO Fast transient monitor £150
KEMO DP11 100khz Phase meter (new) £150
SCHLUMBERGER 7702 Digital transmission analyser £995
BRUEL & KJAER 2511 Vibration meter £750
BRUEL & KJAER 2203 Precision sound level meter/WB0812 filter £450
BRUEL & KJAER 1022 Beat frequency oscillator £400
BRUEL & KJAER 4709 Frequency response analyser £250
BRUEL & KJAER 2305 Level recorder £200
BRUEL & KJAER 2425 0.5hz-500khz Electronic voltmeter £195
BRUEL & KJAER 2971 Phase meter £450
HP5342A 500mhz-18ghz Microwave frequency meter OPT001/003 ..... £1500
HP3779A Primary multiplex analyser £500
HP3780A Pattern generator/error detector £350
HP3762A Data generator £300
HP11667A DC-18ghz Power splitter (new) £495
HP8405A 1mhz-1000mhz Vector voltmeter £300
HP3400A True RMS voltmeter (analogue) £145
HP3403C True RMS voltmeter (digital) £150
HP3406A 10khz-1200mhz Broadband sampling voltmeter £200
HP3465A 4.5 Digit multimeter (LED) £150
HP3466A 4.4 Digit autoranging multimeter (LED) £200
HP3468A 5.5 Digit multimeter/electronic auto calibration £400
HP5004A Signature analyser £200
HP5005A Signature multimeter £400
HP8750A Storage normaliser £350
HP355D DC-1000mhz VHF attenuator 50 ohm 0-120db £150
HP11710A Down convertor £250
HP423A 10mhz-12.4ghz Crystal detector £150
HP11052A Logic comparator £75
HP1600A/1607A 32 Bit logic analyser £100
HP436A Digital RF power meter £650
HP432A/478A 10mhz-10ghz Power meter £350
HP435A/8482H 100khz-4.2ghz Power meter £550
HP435B/8481A 10mhz-18ghz Power meter £850
HP435B/8481A/8484A/11708A 10mhz-18ghz supplied new in hp case/manuals £1200
MARCONI 6950/6910 10mhz-20ghz £850
MARCONI 6593A VSWR indicator £495

MARCONI 6440/6421 10mhz-12.4ghz £250
MARCONI TF2432A 10hz-560mhz Frequency counter £150
MARCONI TF2331A Distortion factor meter £175
MARCONI TF2300B Modulation meter 1200mhz £200
MARCONI TF2306 Programmable interface unit £400
MARCONI TF2603 50khz-1500mhz RF millivoltmeter £75
MARCONI TF2160 20hz-20khz Monitored AF attenuator £50
MARCONI TF2910/4 TV linear distortion analyser £250
MARCONI TF2913 Test line generator/insertor £250
MARCONI TF2914A Insertion signal generator £250
BIRD 43 Thruline wattmeters £75
BIRD 81B Termaline 80 watt coaxial resistor £85
BIRD 8343 Teruline 100 watt 6db attenuator £85
BIRD 8325 Coaxial 500 watt 30db attenuator £200
BIRD 8329 Coaxial 2000 watt 30db attenuator £500
DYMAR 2085 AF power meter £175
FARNELL RB 1030/35 Electronic load £495
FARNELL TM8 10khz-1000mhz True RMS sampling RF meter (as new) £350
FARNELL TOPS 3D Triple output digital power supply £225
FARNELL LA520 1.5mhz-520mhz RF amplifier £150
FARNELL L30 BT 0-30v 1amp Dual power supply £65
FARNELL L30E 0-30v 5amp power supply £85
TEKTRONIX 318 50mhz 16 channel logic analyser £400
SYSTEMS VIDEO 1152/1155 Compact 19" waveform monitor+ vectorscope £1000
WAYNE KERR CT496 LCR meter battery portable £95
RADIOMETER TRB11 RLC Component comparator £150
WANDEL & GOLTERMAN PSS19 Level generator £650
NARDA 769/6 150 watt 6db attenuators £65
NARDA 3001 450mhz-950mhz Directional coupler 10db 20db or 30db £100
NARDA 3044B-20 3.7ghz-8.3ghz 20db Directional coupler £150
NARDA 3004-10 4-10ghz 10db Directional coupler £195
IWATSU SC7104 10hz-1000mhz Frequency counter (new) £295
SAYROSA AM41 1.5mhz-2ghz Automatic modulation meters £195
SIEMENS U2233 Psophometer (new) £400
SIEMENS D2108 200khz-30mhz Level meter £650
SIEMENS W2108 200khz-30mhz Level oscillator £650
RACAL 9063 Two tone oscillator £225
RACAL 9009 1500mhz Automatic modulation meter £275
RACAL DANA 9904M 50mhz Timer counter £100
RACAL DANA 9914 10hz-200mhz Frequency counter £125
RACAL DANA 9915 10hz-560mhz Frequency counter £150
RACAL DANA 9000 10hz-512mhz Microprocessing timer counter £175
RACAL DANA 9916 10hz-560mhz Frequency counter £200
RACAL DANA 9919 10hz-1100mhz Frequency counter £300
RACAL DANA 9921 10hz-3ghz Frequency counter £425
RACAL DANA 6000 Microprocessing digital voltmeter £250
RACAL DANA 9303 True RMS RF level meter LCD £450
RACAL DANA 9232 Dual output power supply 0-30 volt 0-2amp £150
RACAL DANA 488 IEEE-STD Bus analyser £125
RACAL DANA 1002 Thermal printer £100
POLAR B2000A uP Bus tester £125
RACAL RA1218 30mhz Communications receiver £350
AVO 8 MK5 Testmeters with test probes/case £75

SPECIAL OFFERS

BECKMAN DM110 Digital multimeter with case and probes £50
SOLARTRON 7045 4.5 Digit bench multimeter battery/mains £60
SMITHS 3" Diameter altimeters £65
BIRD 43 Thruline wattmeters £75
SIEMENS PDRM82 portable LCD radiation meters (new) £45
FARNELL LFM2 Audio oscillators sine/square £45
MARCONI TF1101 High output RC oscillators £45
HP431C DC-12ghz RF power meter and HP 12ghz attenuator £50

ALL PRICES PLUS VAT AND CARRIAGE · ALL EQUIPMENT SUPPLIED WITH 30 DAYS WARRANTY

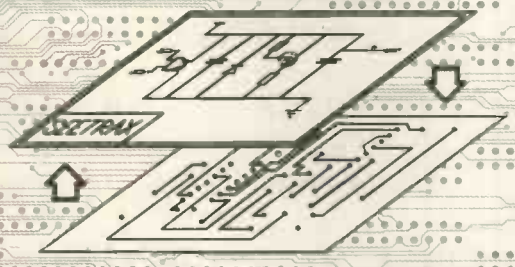
86 Bishopgate Street, Leeds LS1 4BB
Tel: (0532) 435649 Fax: (0532) 426881

CIRCLE NO. 115 ON REPLY CARD

SEETRAX CAE - RANGER - PCB DESIGN

Ranger1 £100

* Schematic capture linked to PCB
* Parts and wiring list entry
* Outline (footprint) library editor
* Manual board layout
* Full design rule checker
* Back annotation (linked to schematic)
* Power, memory and signal autorouter - £50



Ranger2 £599

All the features of Ranger1 plus
* Gate & pin swapping (linked to schematic)
* Track highlighting
* Auto track necking
* Copper flood fill
* Power planes (heat-relief & anti pads)
* Rip-up & retry autorouter

Ranger3 £3500

All the features of Ranger2 plus
* UNIX or DOS versions
* 1 Micron resolution and angles to 1/10th degree
* Hierarchical or flat schematic
* Unlimited design size
* Any-shaped pad
* Split power planes
* Optional on-line DRC
* 100% rip-up & retry, push & shove autorouter

Outputs to:

* 9/9 and 24 pin dot-matrix printers
* HP Desk/Laser Jet, Canon BJet, Postscript (R3 only)
* HP GL, Houston Instruments plotters
* Gerber photoplotters
* NC Drill Excellon, Sieb & Meyer
* AutoCAD DXF

All systems upward compatible. Trade-in deals available.

Call *Seetrax CAE* for further information/demo packs.
Tel 0705 591037 Fax 0705 599036

Seetrax CAE, Hinton Daubney House, Broadway Lane,
Lovedean, Hampshire, PO8 0SG

All trademarks acknowledged.

CIRCLE NO. 116 ON REPLY CARD

INTERFACING WITH C

by

HOWARD HUTCHINGS

Interfacing with C can be obtained from Lorraine Spindler, Room L333, Quadrant House, The Quadrant, Sutton, Surrey SM5 2AS. Please make cheques for £14.95 (which includes postage and packing) payable to Reed Business Publishing Group. Alternatively, you can telephone your order, quoting a credit card number. Telephone 081-652 3614.
A disk containing all the example listings used in this book is available at £29.96. Please specify size required.

C HERE!

If you have followed our series on the use of the C programming language, then you will recognise its value to the practising engineer.

But, rather than turning up old issues of the journal to check your design for a digital filter, why not have all the articles collected together in one book, Interfacing with C?

The book is a storehouse of information that will be of lasting value to anyone involved in the design of filters, A-to-D conversion, convolution, Fourier and many other applications, with not a soldering iron in sight.

To complement the published series, Howard Hutchings has written additional chapters on D-to-A and A-to-D conversion, waveform synthesis and audio special effects, including echo and reverberation. An appendix provides a "getting started" introduction to the running of the many programs scattered throughout the book.

This is a practical guide to real-time programming, the programs provided having been tested and proved. It is a distillation of the teaching of computer-assisted engineering at Humberside Polytechnic, at which Dr Hutchings is a senior lecturer.

Source code listings for the programs described in the book are available on disk.

Connecting a speaker to an amplifier isn't just a matter of linking a piece of wire. There are reactances, impedances and phase to consider – all conspiring to upset stability. Ivor Brown shows how to avoid trouble.

Between amplifier and speaker

In audio systems, there is usually more than just a length of cable between the power amplifier circuit and the loudspeaker; additional components are there because the amplifier designer has no control over the load that the amplifier will have to feed. They are intended to isolate load variations from the amplifier circuit so that it operates as intended for all reasonable loads.

Usually, a series resistor-capacitor network is across the amplifier's output terminals and an inductor of a few microhenries goes between the output of the circuit and the live speaker terminal. The *RC* network provides an effective low-impedance load at high frequencies where, for example, an electromagnetic loudspeaker will have an impedance much larger than its nominal value. The inductor removes the effects of significant capacitive loads on the amplifier, such as may be encountered with long leads. The amplifier 'looks into' the inductor, whose impedance rises with frequency and buffers the capacitance loading at these frequencies. It sounds very simple, but analysis reveals that the circuit's operation is rather complex.

Why are amplifiers sensitive to reactive loads? Most employ some negative feedback to linearise their behaviour, the stability of the feedback loop being all-important. To ensure adequate stability margins for a multi-stage amplifier with a resistive load is difficult enough, but to do it for unspecified reactive loads is virtually impossible. An inductive load may cause the open-loop gain of the amplifier to rise at high frequencies and prevent satisfactory stability margins being obtained. A capacitive load will introduce additional phase lag into the forward gain path and this may also lead to unsatisfactory stability margins.

Negative feedback has had a bad press over the last few years, some designers making a feature of using as little as possible. There is nothing wrong with the technique in itself, but its use without appreciating and avoiding its limitations can – and does – cause problems[1]. Most importantly, open-loop bandwidth of the

amplifier must cover the whole audio frequency range. Outside these frequencies the gain must be rolled-off in a controlled manner to ensure satisfactory gain and phase stability margins; behaviour made difficult to achieve by unspecified reactive loads. Since most designs employ dc-coupled feedback loops, serious stability problems are normally confined to high frequencies above 10kHz, extending to around 1MHz[2,3].

Series inductor

To start, assume a load consisting of a resistive loudspeaker plus some shunt capacitance. Inductor L, shunt capacitance C and the load resistor R form the damped resonant circuit of **Fig. 1**. In practice, the capacitance is mainly due to the speaker cable, but a well designed amplifier should be stable with appreciably larger values than those expected from this source. This implies that the design has good stability margins and component tolerances between samples are unlikely to be a problem. Also, although having an amplifier remote from the speaker is not a good idea, it may be operated in this way and must not be unstable even with very long cables.

Equations in the diagram describe the impedance of the network. When the imaginary parts in the numerator and denominator of the right hand impedance expression are equal, it is resistive. The equation for the zero-phase frequency, zpf, shows it is real only for capacitance above a minimum value (C_{min}); with C_{min} in circuit, zpf tends to zero, the significance of zpf being that, below it, the impedance of the network is capacitive and, in spite of the inductor, will capacitively load the system. Above it, the impedance is inductive with leading phase.

Figure 2 is zpf shown plotted against capacitance for two values of inductor and a 8Ω resistor; also shown is the frequency calculated from the LC product. With large values of capacitance, circuit Q is high and the two frequencies are virtually identical. As the capacitance is reduced towards the minimum value, Q is lowered and zpf differs appreciably from the LC frequency. The larger inductor lowers the zpf for a given value of C and hence the frequency range where the amplifier experiences capacitive loading.

With a larger load resistor, C_{min} is lower and the curves are shifted upwards and to the left.

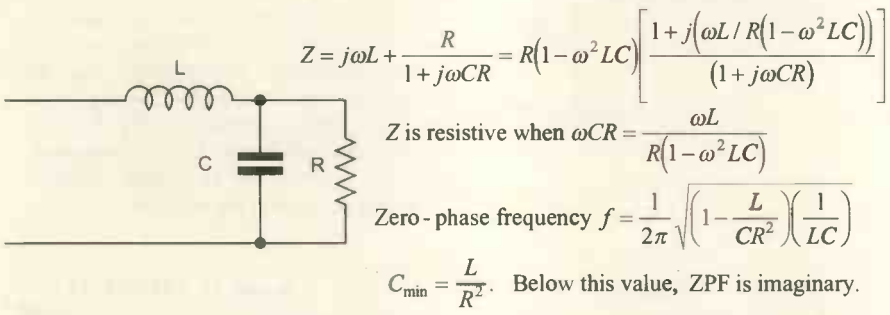


Fig. 1. Impedance and frequency for zero phase of the deceptively simple circuit with series L, cable capacitance and resistive speaker load. Above and below zero-phase frequency, impedance is inductive and capacitive respectively.

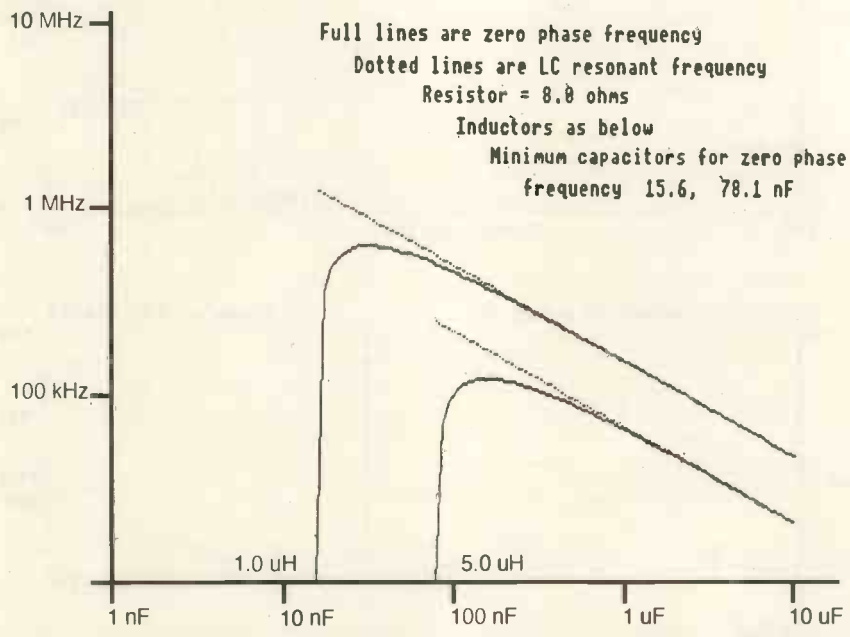


Fig. 2. Zero-phase frequency against C, with L of 1μH and 5μH and an 8Ω resistor in the circuit of Fig. 1.

"Negative feedback has had a bad press over the last few years, some designers making a feature of using as little as possible. There is nothing wrong with the technique in itself, but its use without appreciating and avoiding its limitations can – and does – cause problems."

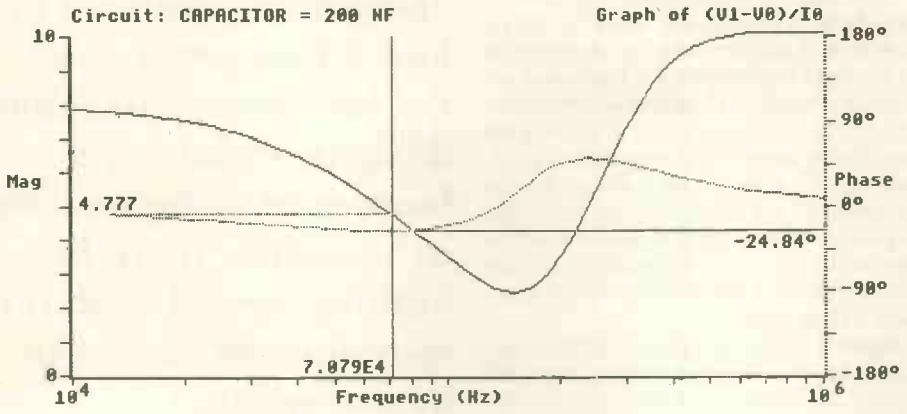
The zpf curve follows the LC line to lower values of C and reaches higher frequencies, as expected because circuit Q is increased. Before proceeding, the series RC network must be added across the input, 10Ω and 100nF being typical values. In the introduction I suggested that its purpose was to prevent the inductive speaker presenting a high impedance load at high frequencies, but now a physical inductance is connected to the amplifier output.

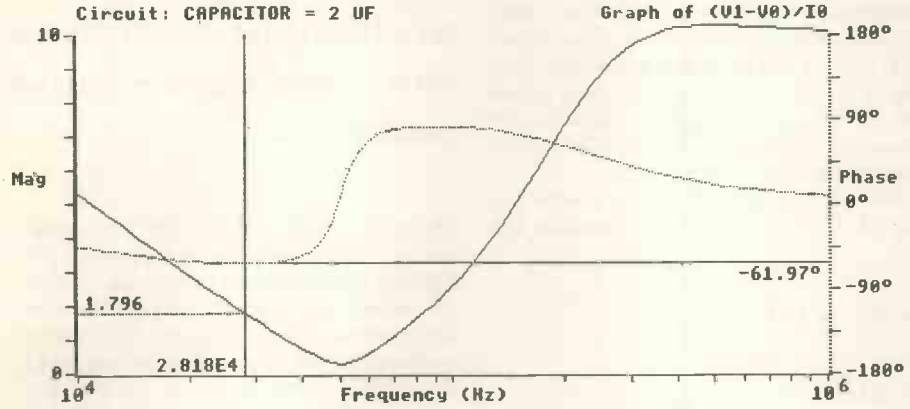
Figure 3 shows the circuit as so far described and two simulated responses of its input impedance for shunt capacitances of 200nF and 2μF, showing the lower zpf and the larger maximum phase lag occurring at a lower frequency for the larger C. The input RC network increases the maximum phase lag slightly but, more importantly, reduces the magnitude at higher frequencies. Without the network, the phase would tend towards +90°.

Connecting a load of 8Ω and 2.2μF in parallel is a common test to assess stability margins. It will almost certainly cause a square-wave output to ring severely on the transitions, but the ringing should die away quickly, indicating that the amplifier has adequate margins. Most of the ringing may be due to the transmission characteristic of the LCR circuit with the waveform at the input side of the inductor looking much better. In this case the additional phase lag at relatively low frequencies is not causing a problem.

However, with an appreciably lower capacitor, more representative of cable capacitance, things may not be so good. Maximum phase lag is less, but it occurs at higher frequencies; active devices in the amplifier are also causing appreciable lags and the circuit may not be able to tolerate the additional loading.

When looking at the loading impedance, one must consider both magnitude and phase. A large magnitude with phase tending to –90° represents a small capacitor which may have little effect. A small magnitude with a smaller





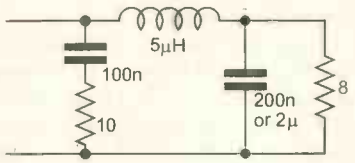


Fig. 3. Additional CR across input of circuit in Fig. 1 reduces impedance magnitude swing at high frequencies. Performance curves are shown on the left.

seeking great accuracy unless an amplifier is being designed for use with one specific speaker system; hardly a practical proposition.

Input impedance responses in Fig. 4 show the result of using the three-component compensation circuit with the 8Ω load replaced by the loudspeaker model. Note the wide variation in magnitude with the scales going up to 25Ω as opposed to 10Ω in Fig. 3.

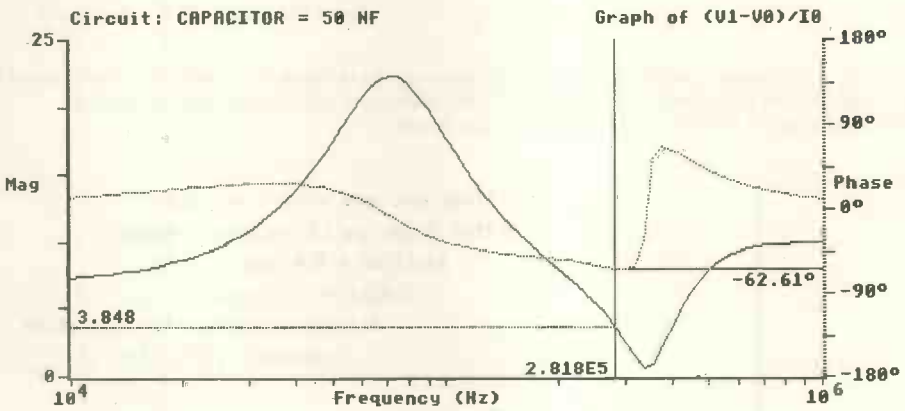
Comparison of the 200nF responses in Figs 3 and 4 reveals how much the loudspeaker model has changed matters for the worse. Maximum phase lag is much greater than before and it occurs at a higher frequency; the magnitude at maximum phase lag is considerably reduced; just the effects we have been trying to avoid!

Figure 1 shows that, for 8Ω and 5µH, the value of C_{min} is 78.1nF. With the simulated speaker, capacitance values below C_{min} do result in an impedance with a lagging phase angle. The upper responses in **Fig. 5** show what happens with just 50nF: a low magnitude with over 60° of lag at around 300kHz. Curves are not shown, but with only 10nF, the phase angle may take an appreciably greater quadrature current component.

Practical loudspeaker loads

At audio frequencies, the impedance of loudspeakers varies widely from the nominal resistive value; however, in the context of this article, it is the impedance above 10kHz that is important. Measurements have been made on a number of 8Ω, two-unit systems and the results suggest that the impedance curves for such systems are not too dissimilar: the magnitude rises gradually from about the nominal value at 10kHz to above 100Ω at 1MHz.

Figure 4 is a reasonable model with typical component values shown. There is no point in



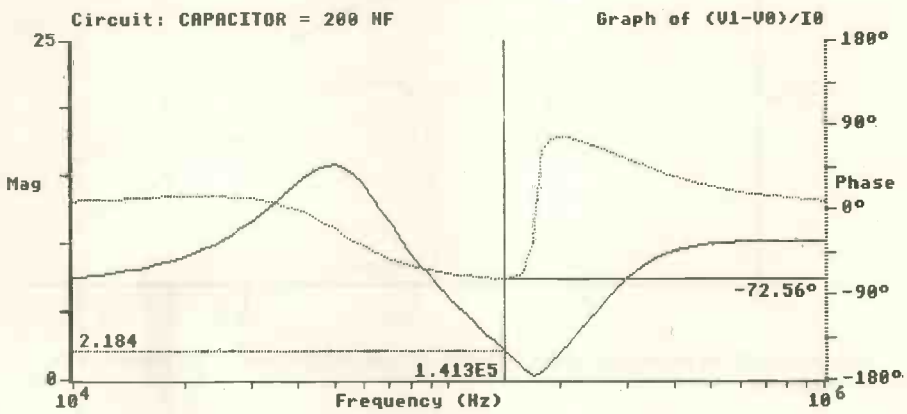
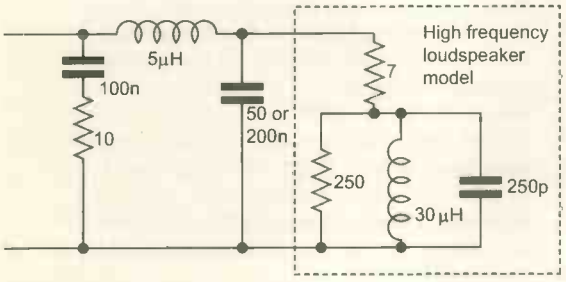


Fig. 4. Three-component circuit of Fig. 2, with a speaker instead of an 8Ω resistor. Both magnitude and phase swings are much worse, even though magnitude scale is now 25Ω. Performance curves are shown on the right.



lag approaches 45° over the range 100kHz-700kHz.

Inductive speaker impedance is again causing a problem and second series *RC* network must be added to ground from the load side of the inductor. Considering the other impedances in the circuit and the likely low output impedance of the amplifier, values of 10Ω and 500nF form a negligible shunt across the speaker at audio frequencies, and largely overcome the problem. Figure 5 is the complete circuit and simulated input-impedance plots for three shunt capacitor values, two the same as in Fig. 4; the reduced magnitude variation, on a 0 to 10Ω scale, and the smaller lag angles are clearly shown. Responses for the larger capacitors are not very different from those shown in Fig. 3.

Investigation of the five-component isolation circuit with the loudspeaker model replaced by a 8Ω resistor gives responses that are also not very different from those in Fig. 3. There is only a small phase lag for capacitors less than C_{min}. With larger values, the magnitude and phase at the maximum-phase-lag frequency are within 20% and 10° respectively, although this condition does occur at a slightly lower frequency. To make the test more stringent, a larger load resistor could be used to increase the lag angle somewhat.

A point that needs watching is the dissipation in the 10Ω resistor of the second *RC* network. A sinusoidal output of 100W at 1kHz into a 8Ω load will give less than 100mW in the 10Ω resistor but, at 10kHz, the power increases to about 8W. Under normal use with music signals, this will present no problem, but if high-frequency, high-power testing is attempted, a suitably rated resistor must be used. Similar considerations apply to the first *RC* network, but the smaller capacitor reduces the 10kHz dissipation to less than half a watt.

Conclusions

High-frequency impedance of real loudspeakers makes the three-component load isolation circuit with shunt *CR* and series *L* perform relatively ineffectively.

Connecting a second *CR* network in series across the output terminals to the speaker largely compensates for the speaker impedance, the resulting five-component isolation circuit presenting a more easily driven load to the amplifier. When loaded by a loudspeaker, it performs in a similar manner to the three-component circuit with a resistive load. Provided a range of capacitors are used with the five-component circuit, testing with a load resistor and capacitor in parallel is meaningful. It provides a loading not too far removed from what may be encountered in practice.

This article is intended as a general discussion of the effects of loading on amplifiers. Computer analysis and simulation cannot be performed in general terms, so component values have had to be introduced to illustrate the points discussed. I do not suggest that they are suitable for general application and it is left for designers to evaluate the component values most suited to their particular amplifier. ■

References

1. I J A Brown. Feedback and fets in audio power amplifiers. *Electronics and Wireless World*, vol. 95, No 1636, February 1989.
2. Savant, Roden and Carpenter. *Electronic Design, Circuits and Systems*. Benjamin/Cummings 1991.
3. Schilling and Belove. *Electronic Circuits, Discrete and Integrated*, 3rd ed. McGraw-Hill 1989.

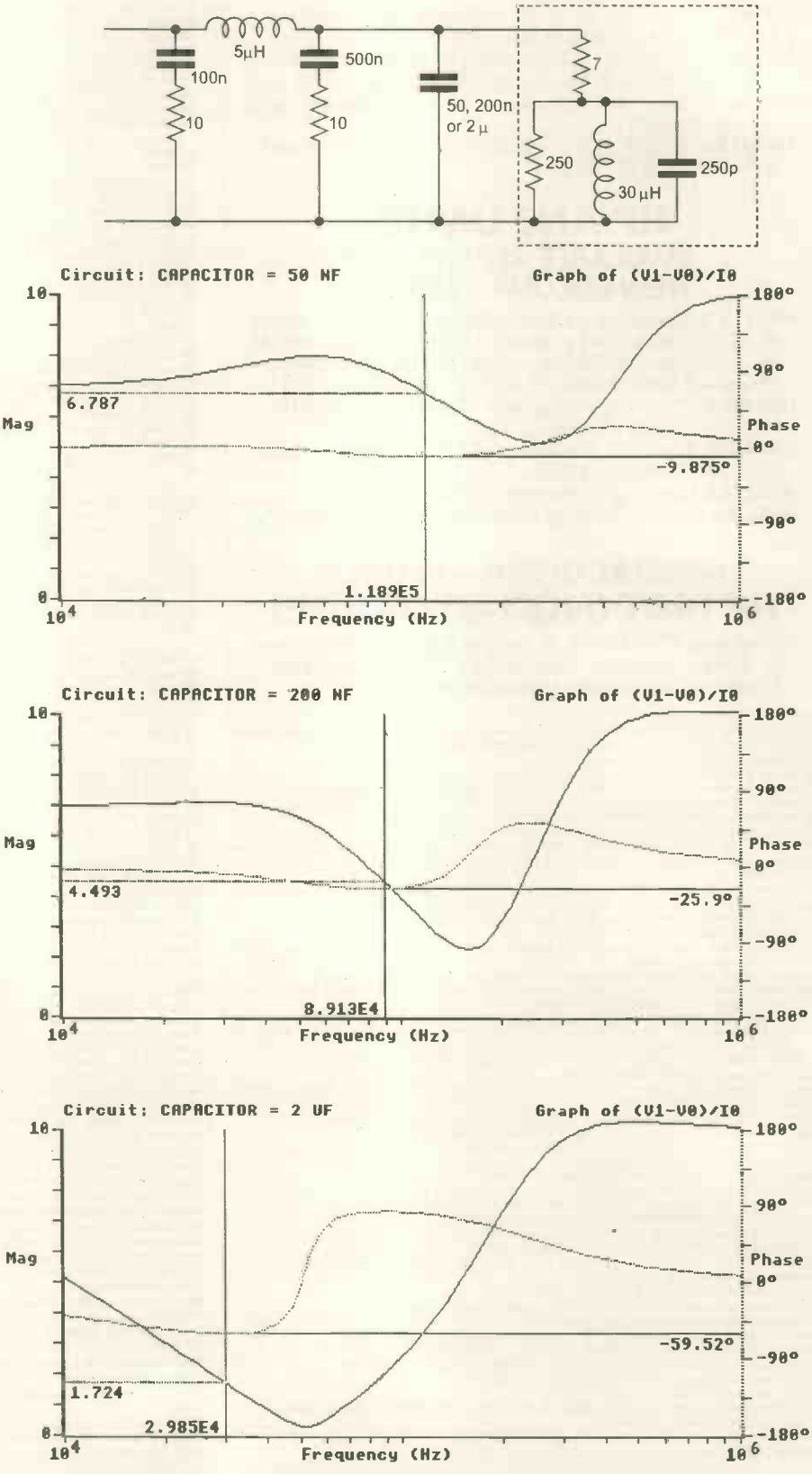


Fig. 5. Second RC after the L solves the problem and this is the complete circuit. Magnitude scales on graphs are back to 10Ω.

SMALL SELECTION ONLY LISTED – EXPORT TRADE AND QUANTITY DISCOUNTS – RING US FOR YOUR REQUIREMENTS WHICH MAY BE IN STOCK

NEW LOW PRICE – NEW COLOUR
HP141T SPECTRUM ANALYSERS
TESTED

HP141T + 8552A or B IF – 8553B RF – 1kHz – 110Mc/s – A IF £600 or B IF – £700.

HP141T + 8552A or B IF – 8554B RF – 100kHz – 1250Mc/s – A IF £800 or B IF – £900.

HP141T + 8552A or B IF – 8555A RF – 10Mc/s – 18GHz – A IF £1400 or B IF – £1600. The mixer in this unit costs £1000, we test every one for correct gain before despatch.

HP141T + 8552A or B IF – 8556A RF – 20Hz – 300kHz – A IF £600 or B IF – £700.

HP ANZ UNITS
AVAILABLE SEPARATELY
NEW COLOUR – TESTED

HP141T Mainframe – £350 – 8552A IF – £200 – 8552B IF – £300 – 8553B RF – 1kHz – 110Mc/s – £200 – 8554B RF – 100kHz – 1250Mc/s – £400. 8555A RF – 10Mc/s – 18GHz – £1000. 8556A RF – 20HZ – 300KHZ – £250.

HP8443A Tracking Generator Counter – 100kHz – 110Mc/s – £300 – £400.

HP8445B Tracking Pre-selector DC – 18GHz – £400-£600 or HP8445A – £250.

HP8444A Tracking Generator – £750 – 1300Mc/s.

HP8444A Opt 059 Tracking Generator – £1000 – 1500Mc/s.

SPECIAL OFFER – 14 ONLY
HP140T (NON-STORAGE)

Mainframe Plus 8552A IF Plug-In Plus 8556A RF Plug-In 20Hz – 300kHz Plus 8553B RF Plug-In 1kHz – 110Mc/s. Tested with instructions – £700.

Marconi TF2008 – AM-FM signal generator – also sweeper – 10Kc/s – 510Mc/s – from £250 – tested to £400 as new with manual – probe kit in wooden carrying box.
HP Frequency comb generator type 8406 – £400.
HP Vector Voltmeter type 8405A – £400 to £600 – old or new colour.
HP Sweep Oscillators type 8690 A & B + plug-ins from 10Mc/s to 18GHz also 18-40GHz. P.O.R..
HP Network Analyzer type 8407A + 8412A + 8501A – 100Kc/s – 110Mc/s – £500 – £1000.
HP Amplifier type 8447A – 1-400Mc/s £200 – HP8447F, 1-1300Mc/s £400.
HP Frequency Counter type 5340A – 18GHz £1000 – rear output £800.
HP 8410 – A – B – C Network Analyzer 110Mc/s to 12GHz or 18GHz – plus most other units and displays used in this set-up – 8411a – 8412 – 8413 – 8414 – 8418 – 8740 – 8741 – 8742 – 8743 – 8746 – 8650. From £1000.
Racal/Dana 9301A – 9302 RF Millivoltmeter – 1.5-2GHz – £250-£400.
Racal/Dana Counters 9915M – 9916 – 9917 – 9921 – £150 to £450. Fitted FX standards.
Racal/Dana Modulation Meter type 9009 – 8Mc/s – 1.5GHz – £250.
Marconi RCL Bridge type TF2700 – £150.
Marconi/Saunders Signal Sources type – 6058B – 6070A – 6055A – 6059A – 6057A – 6056 – £250-£350. 400Mc/s to 18GHz.
Marconi TF1245 Circuit Magnification meter + 1246 & 1247 Oscillators – £100-£300.
Marconi microwave 6600A sweep osc., mainframe with 6650 PI – 18-26.5GHz or 6651 PI – 26.5-40GHz – £1000 or PI only £600. MF only £250.
Marconi distortion meter type TF2331 – £150. TF2331A – 200.
Tektronix Plug-Ins 7A13 – 7A14 – 7A18 – 7A24 – 7A26 – 7A11 – 7M11 – 7S11 – 7D10 – 7S12 – S1 – S2 – S6 – S52 – PG506 – SC504 – SG502 – SG503 – SG504 – DC503 –DC508 – DD501 – WR501 – DM501A – FG501A – TG501 – PG502 – DC505A – FG504 – 7B80 + 85–7B92A
Gould J3B test oscillator + manual – £200.
Tektronix Mainframes – 7603 – 7623A – 7613 – 7704A – 7844 – 7904 – TM501 – TM503 – TM506 – 7904 – 7834 – 7104 – 7623 – 7633.
Alltech 757 Spectrum Analyser – 001 22GHz – Digital storage + readout – £2000.
Marconi 6155A Signal Source – 1 to 2GHz – LED readout – £400.
Barr & Stroud Variable filter EF3 0.1Hz – 100kc/s + high pass + low pass – £150.
Marconi TF2163S attenuator – 1GHz. £200.
Farnell power unit H60/50 – £400 tested. H60/25 – £250.
Racal/Dana 9300 RMS voltmeter – £250.
HP 8750A storage normalizer – £400 with lead + S.A or N.A Interface.
Marconi TF2330 – or TF2330A wave analysers – £100-£150.
Racal/Dana signal generator 9082 – 1.5-520Mc/s – £500.
Racal/Dana signal generator 9082H – 1.5-520Mc/s – £600.
Tektronix – 7S14 – 7T11 – 7S11 – 7S12 – S1 – S2 – S39 – S47 – S51 – S52 – S53 – 7M11.
Marconi mod meters type TF2304 – £250.
HP 5065A rubidrum vapour FX standard – £2.5k.
Systron Donner counter type 6054B – 20Mc/s – 24GHz – LED readout – £1k.
Racal/Dana 9083 signal source – two tone – £250.
Systron Donner – signal generator 1702 – synthesized to 1GHz – AM/FM – £600.
Tektronix TM515 mainframe + TM5006 mainframe – £450 – £850.
Rhodes & Schwartz power signal generator SLRD-280 – 2750Mc/s – £250-£600.
Ball Efratom rubidrum standard PT256B-FRKL – £1000.
Farnell electronic load type RB1030-35 – £350.
Racal/Dana counters – 9904 – 9905 – 9906 – 9915 – 9916 – 9917 – 9921 – 50Mc/s – 3GHz – £100-£450 – all fitted with FX standards.
HP4815A RF vector impedance meter c/w probe – £500-£600.
Marconi TF2092 noise receiver. A, B or C plus filters – £100-£350.
Marconi TF2091 noise generator. A, B or C plus filters – £100-£350.
HP180TR, HP182T mainframes £300-£500.
Fluke 8506A thermal RMS digital multimeter. £400.
Philips panoramic receiver type PM7900 – 1 to 20GHz – £400.
Marconi 6700A sweep oscillator + 6730A – 1 to 2GHz – £500.
HP8505A network ANZ + 8503A S parameter test set + 8501A normalizer – £4k.
Racal/Dana VLF frequency standard equipment. Tracer receiver type 900A + difference meter type 527E + rubidium standard type 9475 – £2750.
HP signal generators type 626 – 628 – frequency 10GHz – 21GHz.
HP 432A – 435A or B – 436A – power meters + powerheads – Mc/s – 40GHz – £200-£1000.
Bradley oscilloscope calibrator type 192 – £600.
Barr & Stroud variable filter EF3 0.1Hz – 100Kc/s + high pass + low pass – £150.
Marconi TF2370 spectrum ANZ – 110Mc/s – £900.
Marconi TF2370 spectrum ANZ + TK2375 FX extender 1250Mc/s + 1st gen – £1.5k.
HP8614A signal generator 800Mc/s – 2.4GHz, new colour £400.
HP8616A signal gen 1.8GHz – 4.5GHz, new colour £400.
HP 3325A syn function gen 20Mc/s – £1500.
HP 3336A or B syn level generator – £500-£600.
HP 3586B or C selective level meter – £750-£1000.
HP 3575A gain phase meter 1Hz – 13Mc/s – £400.
HP 8671A syn microwave 2 – 6.2GHz – £2k.
HP 8683D S/G microwave 2.3 – 13GHz – opt 001 – 003 – £4.5k.
HP 8660 A-B-C syn S/G. AM + FM + 10Kc/s to 110Mc/s PI – 1Mc/s to 1300Mc/s – 1Mc/s to 2500Mc/s – £750-£2800.
HP 8640B S/G AM-FM 512Mc/s or 1024Mc/s. Opt 001 or 002 or 003 – £800-£1250.
HP 8656A S/G AM-FM 0.1 – 990Mc/s – £1500.
HP 8622B Sweep PI – 01 – 2.4GHz + ATT – £1750.
HP 8629A Sweep PI – 2 – 18GHz – £1000.
HP 86290B Sweep PI – 2 – 18GHz – £1250.
HP 86 Series PI's in stock – splitband from 10Mc/s – 18.6GHz – £250-£1k.
HP 8620C Mainframe – £250. IEEE – £500.
HP 8615A Programmable signal source – 1MHz – 50Mc/s – opt 002 – £1k.
HP 8601A Sweep generator .1 – 110Mc/s – £300.
HP 4261A LCR meter + 16038A test leads – £400.
HP 4271B LCR meter 1MHz digital meter + 16063A test adaptor – £850.
HP 4342A Q meter 22kHz – 70Mc/s 16462A + qty of 10 inductors – £850.
HP 3488A HP – IB switch control unit – £500 + control modules various – £175 each.
HP 3561A Dynamic signal ANZ – £3k.
HP 8160A 50Mc/s programmable pulse generator – £1400.
HP 853A MF ANZ + 8558B – 0.1 – 1500Mc/s – £2500.
HP 8349A Microwave Amp 2 – 20GHz Solid state – £1500
HP 3585A Analyser 20Hz – 40Mc/s – £4k.
HP 8569B Analyser .01 – 22GHz – £5k.
HP 3580A Analyser 5Hz – 50kHz – £1k.
HP 1980B Oscilloscope measurement system – £600.
HP 3455A Digital voltmeter – £500.
HP 3437A System voltmeter – £300.
HP 3581C Selective voltmeter – £500.
HP 5370A Universal time interval counter – £450.
HP 5335A Universal counter – 200Mc/s – £500.
HP 5328A Universal counter – 500Mc/s – £250.
HP 6034A System power supply – 0 – 60V – 0 – 10 amps – £500.
HP 3960A 3964A Instrumentation tape recorders – £300-£500.
HP 5150A Thermal printer – £250.
HP 1645A Data error analyser – £150.
HP 4437A Attenuator – £150.
HP 3717A 70Mc/s modulator – £400.
HP 3710A – 3715A – 3716A – 3702B – 3703B – 3705A – 3711A – 3791B – 3712A – 3793B microwave link analyser – P.O.R.
HP 3730A+B RF down converter – P.O.R.
HP 3552A Transmission test set – £400.
HP 3763A Error detector – £500.
HP 3764A Digital transmission analyser – £600.
HP 3770A Amp delay distortion analyser – £400.
HP 3780A Pattern generator detector – £400.
HP 3781A Pattern generator – £400.
HP 3781B Pattern generator (bell) – £300.
HP 3782A Error detector – £400.
HP 3782B Error detector (bell) – £300.
HP 3785A Jitter generator + receiver – £750-£1k.
HP 8006A Word generator – £100-£150.
HP 8016A Word generator – £250.
HP 8170A Logic pattern generator – £500.
HP 59401A Bus system analyser – £350.
HP 59500A Multiprogrammer HP – IB – £300.
Philips PM5390 RF syn – 0.1 – 1GHz – AM + FM – £1250.
Philips PM5519 Colour T.V. pattern generator – £250.
S.A. Spectral Dynamics SD345 spectrascope 111 – LF ANZ – £2500.
Tektronix R7912 Transient waveform digitizer – programmable – £400.
Tektronix 496 Analyzer 1kHz – 1.8GHz – £3.5k.
Tektronix TR503 + TM503 tracking generator 0.1 – 1.8GHz – £1k – or TR502.
Tektronix 576 Curve tracer + adaptors – £900.
Tektronix 577 Curve tracer + adaptors – £900.
Tektronix 1502/1503 TDR cable test set – £1000.
Tektronix 7L5 LF analyser – 0 – 5Mc/s – £800. OPT 25 – £1000.
Tektronix AM503 Current probe + TM501 m/frame – £1000.
Tektronix SC501 – SC502 – SC503 – SC504 oscilloscopes – £75-£350.
Tektronix 465 – 465B – 475 – 2213A – 2215 – 2225 – 2235 – 2245 – 2246 – £250-£1000.
Kikusui 100Mc/s Oscilloscope COS6100M – £350.
Farnell PSG520 Signal generator – £400.
Nicolet 3091 LF oscilloscope – £1000.
Racal 1991 – 1992 – 1988 – 1300Mc/s counters – £500-£900.
Tek 2445 150Mc/s oscilloscope – £1400.
Fluke 80K-40 High voltage probe in case – BN – £100.
Racal Recorders – Store 4 – 4D – 7 – 14 channels in stock – £250 – £500.
Racal Store Horse Recorder & control – £400-£750 Tested.
EIP 545 microwave18GHz counter – £1200.
Fluke 510A AC ref standard – 400Hz – £200.
Fluke 355A DC voltage standard – £300.
Schlumberger 5229 Oscilloscope – 500Mc/s – £500.
Solartron 1170 FX response ANZ – LED dislay – £280.
Wiltron 610D Sweep Generator + 6124C PI – 4 – 8GHz – £400.
Wiltron 610D Sweep Generator + 61084D PI – 1Mc/s – 1500Mc/s – £500.
Time Electronics 9814 Voltage calibrator – £750.
Time Electronics 9811 Programmable resistance – £600.
Time Electronics 2004 D.C. voltage standard – £1000.
HP 8699B Sweep PI YIG oscillator .01 – 4GHz – £300. 8690B MF – £250. Both £500.
Schlumberger 1250 Frequency response ANZ – £2500.
Dummy Loads & power att up to 2.5 kilowatts FX up to 18GHz – microwave parts new and ex equipt – relays – attenuators – switches – waveguides – Yigs – SMA –APC7 plugs – adaptors, etc.
B&K Items in stock – ask for list.
W&G Items in stock – ask for list.
Power Supplies Heavy duty + bench in stock – Farnell – HP – Weir – Thurlby – Racal etc. Ask for list.

ITEMS BOUGHT FROM HM GOVERNMENT BEING SURPLUS. PRICE IS EX WORKS. SAE FOR ENQUIRIES. PHONE FOR APPOINTMENT OR FOR DEMONSTRATION OF ANY ITEMS, AVAILABILITY OR PRICE CHANGE. VAT AND CARRIAGE EXTRA

ITEMS MARKED TESTED HAVE 30 DAY WARRANTY. WANTED: TEST EQUIPMENT–VALVES–PLUGS AND SOCKETS–SYNCROS–TRANSMITTING AND RECEIVING EQUIPMENT ETC.

Johns Radio, Whitehall Works, 84 Whitehall Road East, Birkenshaw, Bradford BD11 2ER. Tel. No: (0274) 684007. Fax: 651160

CIRCLE NO. 117 ON REPLY CARD

New null filter replaces twin-T

Using twin-T filters can involve tedious adjustment. Here, Bengt Olsson describes a null filter alternative that offers the advantage of low common-mode distortion, making it highly suitable for thd analysis.

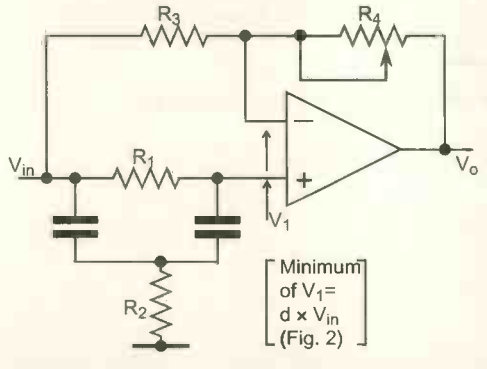
This filter is very simple: it uses a single op amp and provides a buffered output. The basic circuit, **Fig. 1**, consists of a minimal network, with a resonance dip d that is amplified to a complete null by the op amp.

The filter is zeroed in two, preferably orthogonal, directions: gain and phase (frequency). These are separated: the gain adjustment is made with R_4 and the phase is tuned by adjusting the network frequency. To maintain orthogonality both R_1 and R_2 have to be changed proportionally, assuming the two capacitors are equal.

Selectivity

Like the twin-T, this circuit has a low Q, **Fig 3**, and ought to be improved by positive feedback. This involves feeding back part of the op-amp output to R_2, **Fig. 4**. At resonance the output is zero, as if R_2 were grounded, which means that the balance condition at resonance is as it was without feedback. For all other frequencies the gain will be closer to one, resulting in a narrower null.

According to Thévenin, the feedback circuit R_2, R_5 and R_6 can be replaced by only R_5 and R_6, where R_5 is slightly larger than the original R_2. In this way, power dissipation in the feedback network is minimised to practically zero. In spite of this, the equivalent voltage divider has zero impedance. A typical feedback factor is 85%, which gives a second harmonic atten-



$$\text{If } \sqrt{R_1 R_2} = R_0$$

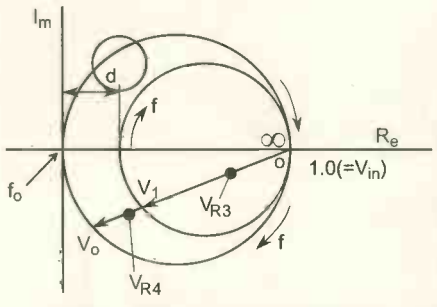
$$C_1 = C_2 = C_0$$

$$2\pi f_0 = \frac{1}{R_0 C_0}$$

$$\frac{1}{d} = 1 + \frac{R_1}{2R_2}$$

$$\frac{R_4}{R_3} = \frac{d}{1-d} = 2\frac{R_2}{R_1}$$

Fig. 1. Basic circuit of the null filter. The resonance dip, d, is amplified to a complete null by the op-amp.



$$d = \frac{2R_2}{2R_2 + R_1}$$

$$\frac{R_4}{R_3} = \frac{d}{1-d}$$

Fig. 2. Plotting V_1, a circle in complex notation, and multiplying by $1+R_4/R_3$ in the namplifier gives a zero for V_0 at frequency f_0.

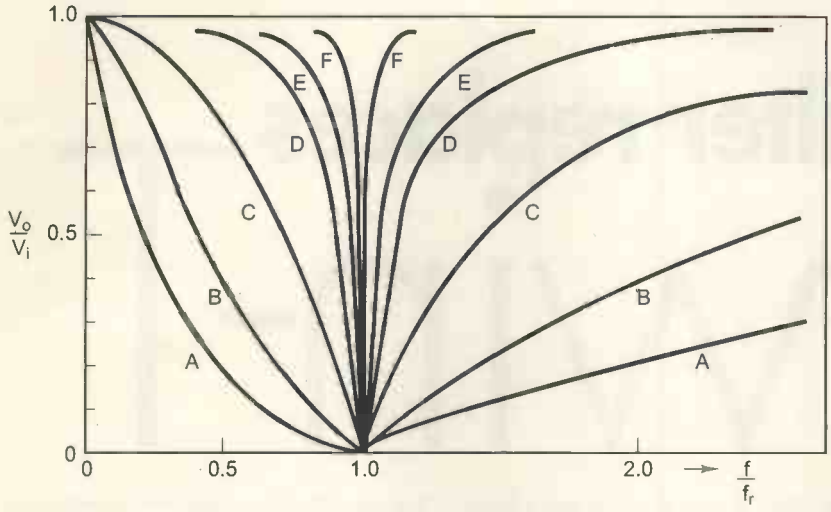
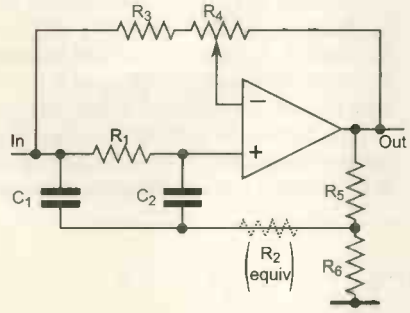


Fig. 3. Positive feedback improves Q of the null filter. These curves show measured frequency response with various amounts of feedback, K.



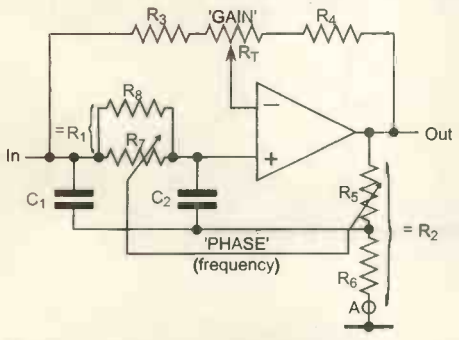
$$R_2 = \frac{R_5 R_6}{R_5 + R_6}$$

Feedback factor

$$K = \frac{R_6}{R_5 + R_6}$$

$$G(s) = \frac{s^2 + 1}{s^2 + 4(1-k)s + 1}$$

Fig. 4. Positive feedback can improve the circuit. Part of the op amp output is fed back to R_2.



Design example

For optimum selectivity:

Make $\frac{R_8}{R_7} = \frac{R_6}{R_5} \approx 6$

(feedback **86%**)

For trim:

Make $\left(\frac{R_1}{R_2} = \right)\frac{R_7}{R_5} = \frac{R_8}{R_6}$ = say 10

Select: R_7 = 50k Lin pot

R_5 = 5k Lin pot

Thus: R_8 = 330k

R_6 = 33k

As $\frac{R_4}{R_3} = \frac{d}{1-d}$: R_3 = 51k, R_4 = 10k, R_7 = 500Ω lin pot

Thus: FB = $\frac{33k}{5k + 33K} \approx 87\%$

Fig. 5. Wide band tuning. The filter can be used to provide orthogonal tuning in a wider range using a ganged potentiometer.

uation (amplitude error) in a thd-analyser of approximately 25%, or 15% for the third, etc). These harmonics can be corrected in a subsequent, slightly peaked, second order high-pass filter, with a cut-off at approximately $1.8f_o$, which will also be used to amplify the distortion products.

Common-mode distortion

At resonance, the low signal level d reduces the common-mode-distortion proportionally. Use of a low-distortion op-amp with sufficient slew-rate will not cause deterioration of the residual signal.

With this method, it is possible to make a simple analyser with a resolution of 10ppm, or better. Each plug-in circuit board may comprise one state-variable oscillator and one null-filter. Operating at frequencies of, say 1, 10 and 30kHz, such an analyser would be useful for audio amplifier testing.

Another interesting feature is that the signal input to the non-inverting terminal is equal to d multiplied by the signal amplitude. Selecting d at 0.1, the op amp can analyse a 200Vp-p sine-wave directly (sine-wave only!). It is therefore possible to measure the output of any size of power amplifier without needing an attenuator.

Wide-band tuning

Figure 5 shows how to provide orthogonal tuning in a wider range using a ganged potentiometer, R_5+R_7. Since the original R_2 is equal to the parallel connection of R_5 and R_6, an equivalent value for R_1 is designed in the same way with R_7 and R_8 in parallel. Ratio R_1/R_2 is constant when tuning, which means that R_4/R_3 (gain) will be constant (see the second equation in **Fig. 2**).

For thd-measurements at one selected frequency, R_5 and R_7 can be low-resistance trimmers in series with larger metal-film resistors. These, and R_t, are set. When automatic zeroing is preferred, the ground connection of R_6 is then used as the input for two quadrature sine-wave voltages.

Summary

The null-filter can be used in a wide range of applications, from a simple hum-suppressing filter to an advanced thd-meter with high resolution. It features low noise. Tests with a 1V input show that the noise is typically 3μV rms. One can clearly read 7μV thd, that is 0.0007% at 20kHz (7ppm). At higher voltages or lower frequencies the resolution is even better.

It is possible to tune the circuit manually using coarse and fine tuning potentiometers, but at lowest distortion level an automatic balancing circuit is preferred, **Fig. 5**. It can be applied to R_6 via the output from an op amp summing the gain and phase error sine-waves.

For improved resolution, it is advantageous to connect an op-amp with 20-40dB gain directly to the output of the circuit. The op amp can be wired as a peaked high-pass second-order filter with gain, which compensates for the response of the null-filter at the second, third, etc, harmonics. ■

WE HAVE THE WIDEST CHOICE OF USED OSCILLOSCOPES IN THE COUNTRY

TEKTRONIX 7000 SERIES OSCILLOSCOPES AVAILABLE FROM £200. PLUG-INS SOLD SEPARATELY

TEKTRONIX 2245A 4 Channel 100MHz Cursor etc £1000
TEKTRONIX 2246A 4 Channel 100MHz Cursor Voltmeter etc £1250
TEKTRONIX 475 Dual Trace 200MHz Delay Sweep £500
TEKTRONIX 465 Dual Trace 100MHz Delay Sweep £400
TEKTRONIX SC504 Dual Trace 80MHz in TM503B £500
IWATSU SS5711C 4 Channel 100MHz Delay Sweep with DMX £500
TRIO 2100 4 Channel 100MHz Delay Sweep £400
TRIO CS2070 4 Channel 70MHz Delay Sweep £450
TEKTRONIX 2215 Dual Trace 60MHz Delay Sweep £450
KIKUSUI COS5060TM 3 Channel 60MHz Delay Sweep £400
HITACHI V650F Dual Trace 60MHz Delay Sweep £350
PHILIPS PM3217 Dua Trace 50MHz Delay Sweep £400
GOULD OS1100 Dual Trace 30MHz Delay Sweep £240
GOULD OS300 Dual Trace 20MHz Delay Sweep £200
TRIO CS1566A Dual Trace 20MHz £200
GOULD OS250B Dual Trace 15MHz £125
HITACHI VC6045 2 Channel 40 MS/s Digital Storage Cursors £1100
LE CROY 9400 Dual Trace 125MHz Digital Storage £1000
GOULD OS4000 Dual Trace 10MHz Digitla Storage £200

THIS IS JUST A SAMPLE. MANY OTHERS AVAILABLE

NEWLETT PACKARD 1740A Oscilloscopes 100MHz Dual Trace Delay Sweep ..... only £350

MARCONI 2018 Synthesized AM/FM Sig Gen 80KHz – 520MHz £700
H.P. 8640B Sig Gen 20Hz – 1024MHz £1000
H.P. 8620C Sweep Oscillator with 86245A 5.9 – 12.4GHz £400
SYSTRON DONNER 1702 Syn AM/FM Sig Gen 100Hz – 1GHz £600
RACAL 9081 Synthesized AM/FM Sig Gen 5 – 520MHz £500
FARNELL SSG520 Synthesized AM/FM Sig Gen 10 – 520MHz £400
MARCONI TF2015 AM/FM Sig Gen 10 – 520MHz £200
MARCONI TF2015 with Synchronizer TF2171 (Lock box) £350
MARCONI TF2002B AM/FM Sig Gen 10KHz – 88MHz with Dig Sync £150
MARCONI/SANDERS 6600A Microwave Sweep Disc 26.5-40GHz £300
H.P. 8690B Microwave Sweep Osc 26.5-40GHz £300
H.P. SMITH ANTENNA type 12-602-4 ..... £7000
H.P. 436A Power Meter with sensor £1000
RACAL INSTRUMENTATION RECORDER type Store 4DN £500
H.P. 3575A Gain Phase Meter 1Hz – 13MHz £400
MARCONI TF2337 Automatic Distortion Meter £200
SAYROSA Automatic Modulation Meter type 2528 ..... £125
RADFORD LD04 Low FDistortion Oscillator £300
RADFORD LDMS2 Low Distortion Measuring Set £300

TEKTRONIX CPS250 Triple Output PSU 2x20V0.5A Var; 5V2A Fixed £225
TEKTRONIX CFG250 Function Gen 0.2Hz – 2MHz Sine/Sq/Tri/TTL £180
TEKTRONIX CDM250 Digital Multimeter 3½ digit LED £180
H.P. 3456A DVM 6½ digit DC/True RMS AC/Res HPIB £600
EIP/DANA 351D Microwave Frequency Counter 20Hz – 18GHz £500
H.P. 5341A Frequency Counter 50MHz – 1.5GHz LED £300
MARCONI 2435 Digital Frequency Meter 2GHz £400
RACAL 1998 Frequency Counter 1.3GHz (Options GPIB & High Stab) £900
RACAL/DANA 1991 Universal Counter/Timer 160MHz 9 digit £800
MARCONI 2437 Universal Counter/Timer DC – 100MHz 8 digit £175
MARCONI 2431A Frequency Counter 10Hz – 200MHz 8 digit £150
MARCONI 2430A Frequency Counter 10Hz – 80MHz 8 digit £125
RACAL 9918 Frequency Counter 10Hz – 520MHz 9 digit £200
RACAL 9913 Frequency Meter 10Hz – 200MHz 8 digit £125
RACAL 9911 Frequency Meter 10Hz – 120MHz 7 digit £100
RACAL 9905 Universal Counter/Timer DC-200MHz 8 digit £150
RACAL 9904 Universal Counter/Timer DC-50MHz 7 digit £175
RACAL 9901 Universal Counter/Timer DC-50MHz 6 digit £100
DATRON 1061A 6½ digit Autocal Multimeter True RMS AC/Current £650
H.P. 3490A 5 digit Multimeter AC/DC/Ohms £200
H.P. 3435A 3½ digit Multimeter AC/DC/Ohms/Current LED £100
PHILIPS PM2534 Multi Function DMM 3½ – 6½ digit GPIB/IEEE £450
SOLARTRON 7150 6½ – 3½ digit DMM with IEEE £400
SOLARTRON 7045 4½ digit Multimeter Volts/Amps/Ohms £80
WAYNE KERR B905 Automatic Precision Bridge 0.05% £900
MARCONI TF2700 Universal Bridge Battery Operated ..... from £150
MARCONI TF1313A Universal LCR Bridge 0.1% £125
WAYNE KERR B424 Digital Component Meter LCR £200
HEATHKIT IB RLC Bridge £60
BRADLEY 192 Oscilloscope Calibrator £600
WILTRON 560 Scaler Network Analyser with Detectors £1000
H.P. 5005A Signature Multimeter £250
FARNELL H30/100 0 – 30 Volts; 0 – 100 Amps Metered £800
FARNELL TVS70 Mk2 70 Volts 5 Amps/35 Volts 10 Amps Metered £200
FARNELL B30/10 30 Volts 10 Amps Variable £200
FARNELL L30E 0 – 30 Volts, 0 – 5 Amps Metered £125
MARCONI (WEIR) TF2154 0 – 30V 1A 0 – 15V 2A; 0 – 7.5V 4A Metered £60
H.P. 6516A 0 – 3KV; 0 – 6MA Metered £150
BRANDENBURG Model 472R +/– 2KV Metered £200
FEEDBACK FG600 Sine/Sq/Tri 0.01Hz – 100Khz £60
LYONS PG71N Pulse Gen PRF 1Hz – 5MHz 10 nanosecs £75
FARNELL PG101 Pulse Gen 100nSecs 10MHz (1 Sec 1Hz) £125
LINDOS LA1 Mk2B Audio Analyser £500
UNAOHM BP501 Audio Analyser £350
PHILIPS PM5518 Colour TV Pattern Generator £1250

B & K VIBRATION SYSTEM (LARGE) P.O.A.
Other B & K Equipment available

NEW EQUIPMENT

HAMEG OSCILLOSCOPE HM1005 Triple Trace 100MHz Delay Timebase £847
HAMEG OSCILLOSCOPE HM604 Dual Trace 60MHz Delay Sweep £653
HAMEG OSCILLOSCOPE HM203. 7 Dual Trace 20MHz Component Tester £362
HAMEG OSCILLOSCOPE HM205. 3 Dual Trace 20MHz Digital Storage £653
All other models available – all oscilloscopes supplied with 2 probes

BLACK STAR EQUIPMENT (P&P all units £5)
APOLLO 10-100MHz Counter Timer Ratio/Period/Time interval etc £222
APOLLO 100-100MHz (As above with more functions) £325
METEOR 100 FREQUENCY COUNTER 100MHz £119
METEOR 600 FREQUENCY COUNTER 600MHz £145
METEOR 1000 FREQUENCY COUNTER 1GHz £189
JUPITOR 500 FUNCTION GEN 0.1Hz-500kHz Sine/Sq/Tri £119
ORION COLOUR BAR GENERATOR Pal/TV/Video £229
All other Black Star Equipment available

OSCILLOSCOPE PROBES Switchable ×1 ×10 (P&P £3) £12

SPECTRUM ANALYSERS

H.P. 853 with 8559A 0.01 – 21GHz £4500
H.P. 3580A LED 5Hz – 50Khz £1000
POLARAD 641-1 10MHz – 18GHz £1500
AMOD AC8281 with AC8211 1700MHz £1500
H.P. 182 with 8558B 100KHz – 1500MHz £1500
H.P. 141T with 8554B & 8552B 500KHz – 1250MHz £1200
H.P. 141T with 8553B & 8552A 1KHz – 110MHz £800
MARCONI TF2370 30Hz – 110MHz £1000
H.P. 8443 Tracking Generators. Available from £300
H.P. 141T Main Frames only. Good Tubes £225

Used Equipment – GUARANTEED. Manuals supplied if possible.
This is a VERY SMALL SAMPLE OF STOCK. SAE or Telephone for lists. Please check availability before ordering.
CARRIAGE all units £16. VAT to be added to Total of Goods and Carriage.

STEWART of READING
110 WYKEHAM ROAD, READING, BERKS RG6 1PL
Telephone: (0734) 268041. Fax: (0734) 351696
Callers Welcome 9am-5.30pm Monday to Friday (until 8pm Thursday)

VISA

CIRCLE NO. 109 ON REPLY CARD

CROSSWARE

CROSS DEVELOPMENT SOFTWARE TOOLS FOR DOS

C · COMPILERS
CROSS · ASSEMBLERS

FULLY SUPPORTED QUALITY SOFTWARE

You might only need a simple absolute cross assembler for your first project. Later you might decide that you need the sophistication of a fully relocatable package (and of course you will want your existing source code to migrate effortlessly with you). You might decide to make C your primary language, with full IEEE floating point maths available whenever you need it. If you do, you will certainly want to keep your options open by being able to integrate C and assembler.

Whatever your choice you will want the benefit of a user friendly environment with a sophisticated multi-file, multi-window editor/workbench and comprehensive on-line help.

That's why we have configured our product range the way we have.

XPC series: absolute cross assemblers @ **£99.00** each
XDS series: relocatable cross assemblers @ **£169.00** each
PSDS series: C compilers & cross assembler @ **£349.00** each

	68000	68020	8051	8048	Z80	8085	6301	6305	6809	65C02	740 (Mitsubishi)	68hc11	8086
XPC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
XDS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
PSDS	✓	✓	✓										

Further information from: (prices exclude VAT and delivery)
CROSSWARE PRODUCTS
Melbourn, Royston, Herts, SG8 6BA, UK
Tel: +44 (0) 1763 261539, Fax: +44 (0) 1763 262983
BBS: +44 (0) 1763 261716 (8-N-1), Internet: sales@crossware.com

CIRCLE NO. 110 ON REPLY CARD

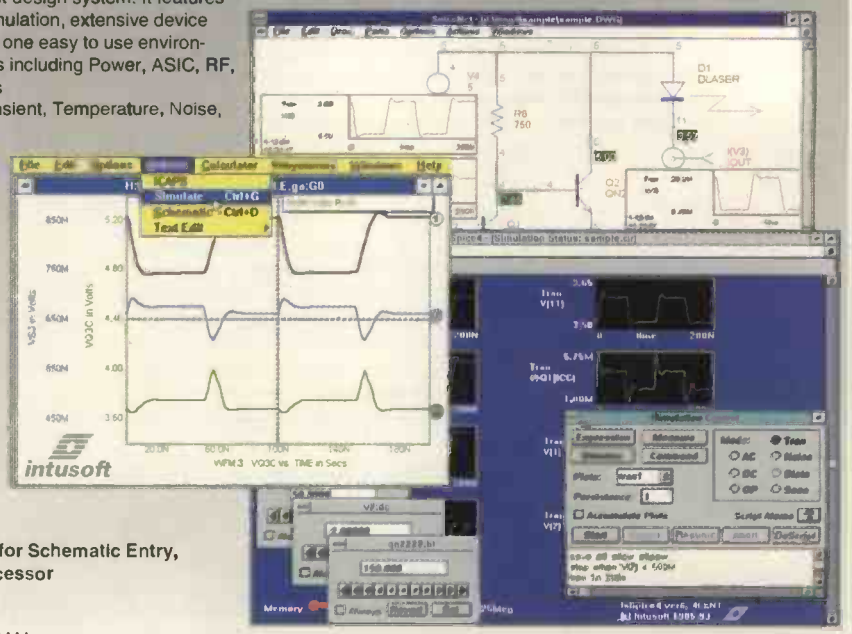
New Analog & Mixed Mode Simulation

Easy To Use, Full Systems from £450 to £2300
1st Class, Free UK technical support

Professional Level .....

ICAP/4, The Virtual Circuit Design Lab, is a complete circuit design system. It features schematic entry, interactive analog and mixed mode simulation, extensive device libraries, and powerful data processing, all integrated in one easy to use environment. With ICAP/4 you can simulate all types of designs including Power, ASIC, RF, Mixed Mode, Control Systems, and Mixed Technologies

- ***Interactive SPICE 3F based Simulator*** (AC, DC, Transient, Temperature, Noise, Distortion, Fourier, Monte Carlo, and Sensitivity (AC/DC) analyses)
- **Native Mixed Mode - Includes 12 state Digital Logic Simulator**
- **Interactive Parameter Sweeping and Measurements**
- **Real Time Cross Probing Directly on the Schematic**
- **Over 6000+ Models Available including Special RF and Vendor Libraries**
- **Multiple Platform Support -** Windows (32s), Windows NT on the PC, Digital Alpha & MIPS, DOS, Macintosh, and Power PC



or Entry Level .....

- ***SPICE 3F based simulator*** (AC, DC, Transient, Temperature, Operating point)
- **UNLIMITED CIRCUIT SIZE**
- **Over 500 device models**
- **Separate upgrades available, when you need them, for Schematic Entry, Models Library, Spice Engine & Graphical Post-processor**
- **Windows & Windows NT**

and both with .....

- **Integrated Schematic Entry**
- **High Performance 32-bit Simulator**
- **Real Time Waveform Display**
- **Third Party Support - Works with all popular schematic entry systems**

The Future Is Interactive!

Call or write for free information and eval SW:
Technology Sources Ltd - Falmouth Avenue -
Newmarket - Suffolk CB8 0LZ
Ph: 0638-561460 Fax: 0638-561721

CIRCLE NO. 118 ON REPLY CARD

Tweaking the diode detector

Important applications for rf detectors of wide dynamic range include the various schemes for linearising radio transmitters. Simple diode detectors can be used, but suffer from a limited dynamic range and – a point which can be important – although amplitude response in the large signal range is linear, it is *not proportional to the signal amplitude*. This is a result of the diode's forward voltage, V_f.

Infinite-impedance detector

Since my interest while I was making this study was in level measurement rather than just detection of the presence of a signal, my thoughts turned to the infinite impedance detector[1]. In this, the detector is a transistor or, in earlier times, a valve. It is in its active range at all times, so one might think that the troublesome curve at the foot of the characteristic in **Fig. A(d)** could be avoided. (See panel on page 123)

My plan was to surround the infinite impedance detector with a high-gain servo loop which would jack up the dc voltage at the emitter of the detector to restore the no-signal dc conditions. The transistor could be a type with a very high frequency cut-off f_t, and both the emitter and the collector could be bypassed at rf, confining rf solely to the

After working through a number of variations on the infinite-impedance detector, Ian Hickman returns to the diode – but finds a wide dynamic range and a way round forward-voltage offset.

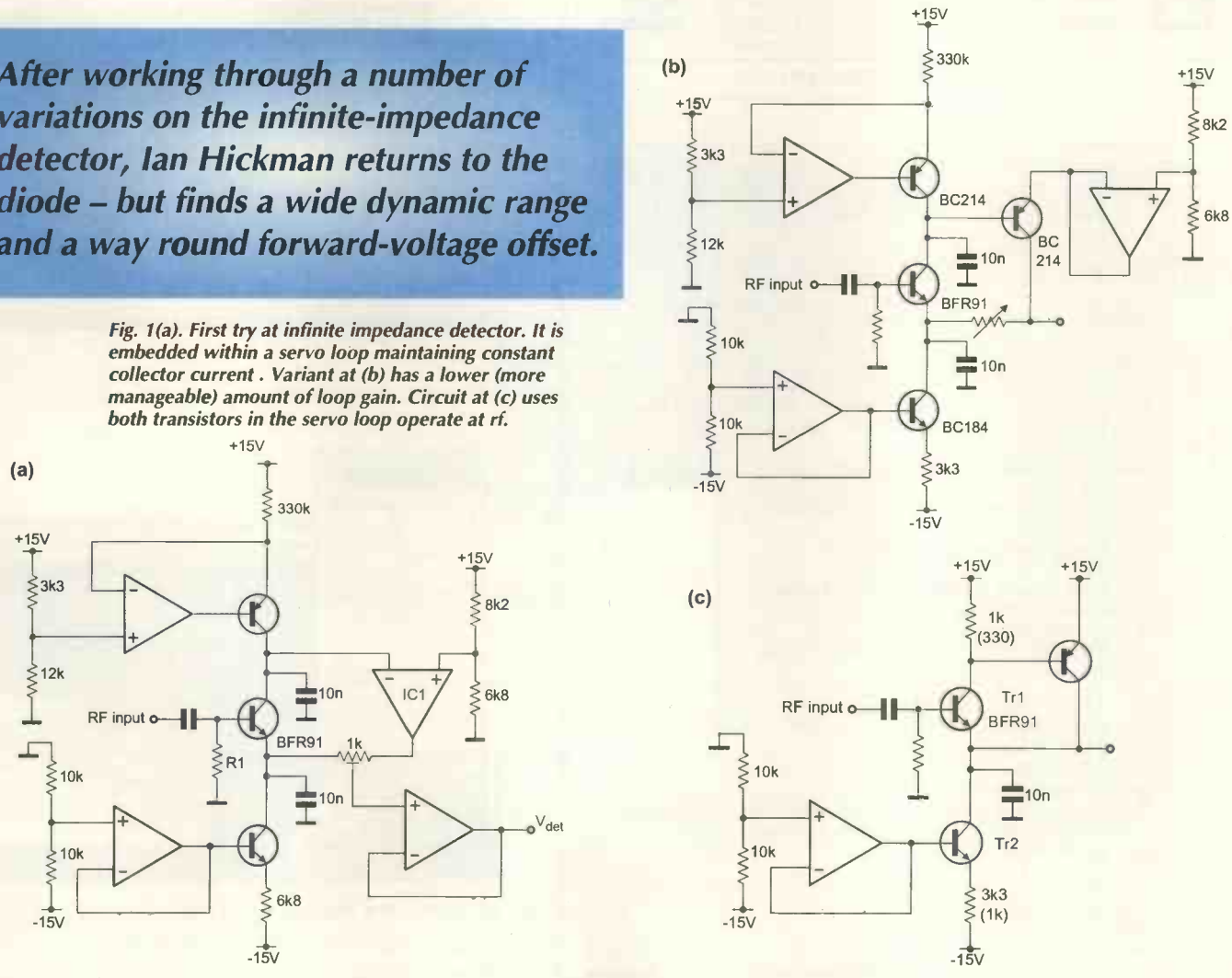


Fig. 1(a). First try at infinite impedance detector. It is embedded within a servo loop maintaining constant collector current . Variant at (b) has a lower (more manageable) amount of loop gain. Circuit at (c) uses both transistors in the servo loop operate at rf.

Diode performance

Figure A(a) shows an ideal diode which has an infinite slope resistance when the voltage at its anode is negative with respect to the cathode, and a slope resistance of zero when forward biased. Such diodes don't exist, but they can be closely approximated, over a limited frequency range, by a combination of one or more real diodes and op-amps. Figure **A(b)** shows a slightly less unrealistic representation of a real diode: the slope resistance when forward biased is still zero, but an anode voltage positive by an amount V_f relative to the cathode must be applied to cause current to flow.

Figure **A(c)** is one step nearer reality, showing as it does a finite diode slope resistance when forward biased. Unfortunately, the resistance does not drop instantly from infinity at forward voltages below V_f to a low constant value at V_f and above, but makes the transition gradually, as the curve at the bottom of the characteristic in Fig. **A(d)** shows. Projecting the characteristic in the forward biased regime back until it cuts the voltage axis gives a value which may be taken approximately as the diode's V_f, the voltage which must be applied before some arbitrary small current flows.

When a practical Fig. A(d) diode is used as an amplitude detector, the detected dc voltage output increases with rf input up to the point where the peak reverse voltage equals V_{br}, the diode reverse breakdown voltage. With decreasing rf input, the detected voltage falls linearly at first, then reaching a point where it falls faster than the input, since the latter no longer comfortably exceeds V_f. This is the square-law region, where the detected voltage is proportional to the applied power rather than to the applied voltage. Where it is simply desired to detect the presence of a signal, rather than accurately to measure its amplitude, the diode can still be successfully used in the square-law region down to the level where the detected voltage starts to disappear into the circuit noise.

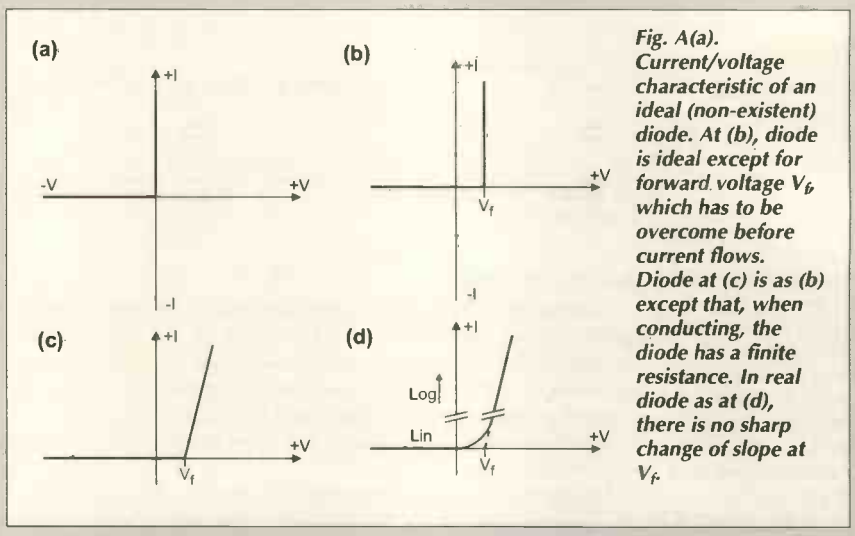
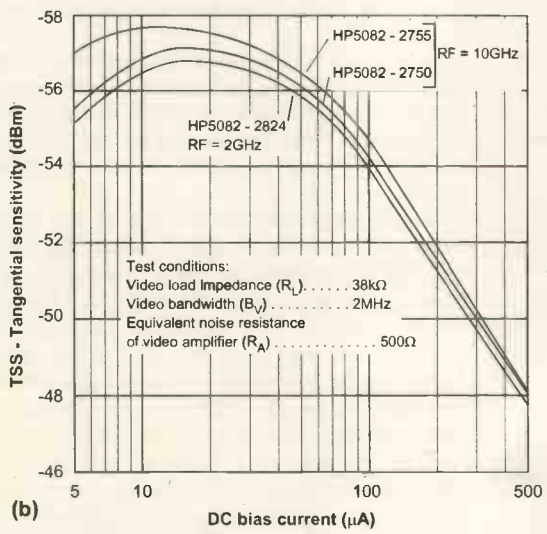


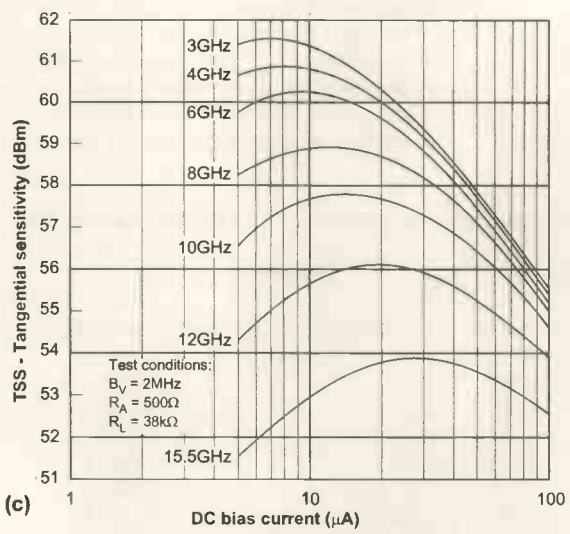
Fig. A(a). Current/voltage characteristic of an ideal (non-existent) diode. At (b), diode is ideal except for forward voltage V_f, which has to be overcome before current flows. Diode at (c) is as (b) except that, when conducting, the diode has a finite resistance. In real diode as at (d), there is no sharp change of slope at V_f.

This level of rf input to the detector is known as the tangential sensitivity, and can be determined by displaying the detected voltage on an oscilloscope whilst driving the diode with an rf signal 100% on/off modulated by a square wave. Tangential sensitivity is the rf level at which the level of the top of the 'grass' in the off periods just coincides with the level of the bottom of the grass in the on periods, as in the middle illustration in **Fig. B(a)**. Results obtained depend to some extent on the oscilloscope intensity setting and upon the operator but, being a quick, simple and easy test, it is widely employed.

Tangential sensitivity can be improved by applying a small forward bias current to the detector diode as shown in Fig. **B(b)** for various diodes. Optimum bias and the improvement that results depend upon frequency. This is illustrated in Fig. **B(c)** for a particular diode, where you can be see that the tangential sensitivity can exceed –60dBm. This means that the sensitivity of a simple diode video receiver is only 35 to 40dB less than that of a superheterodyne receiver. Not only is the diode video receiver much cheaper, simpler and easier to maintain, but it can easily be designed to offer a greater rf bandwidth than a superhet, and it is useful in a variety of applications, both military and civil.

Fig. B(a). Tangential sensitivity of a diode, taken when output is as in middle case. Tangential sensitivity can be improved by applying a small forward bias current to the detector diode, as shown at (b) for various diodes. Optimum value of bias and the improvement that results depends upon frequency, as illustrated at (c) for a particular diode. ((b) and(c) reproduced by courtesy of Hewlett-Packard Ltd, from H-P Application Note 923.)





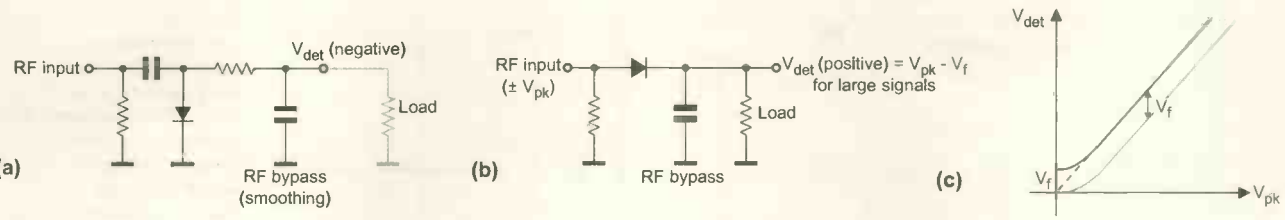


Fig. 2(a). The shunt diode detector needs a dc path to ground at its output to enable it to follow a decreasing rf input level. It produces the same dc detected output for any input level as circuit at (b), the conventional peak detector circuit. By adding V_f to the detected output, as at (c), it becomes proportional to the signal level, except in the low-level square-law area.

base/emitter circuit.

Identical dc conditions, regardless of whether rf was present or not, could be ensured by the use of constant-current generators in the emitter and collector circuits. When two near-perfect constant current generators – one a source and the other a sink – fight each other, their junction is a point of very high voltage gain.

Figure 1(a) shows the resulting pipe-dream, where the op-amp supplies the difference between emitter's constant tail current I_e and the constant collector current I_c. Total gain within the loop includes a contribution equal to the slope resistance of the collector circuit divided by (R_1 plus r_e), where r_e is the common-base input resistance of the transistor. Some quick mental arithmetic showed this to be so great that the roll-off of loop gain had to start at such a low frequency that the circuit's response to a change of input level was inordinately slow. So the op-amp was replaced by a p-n-p transistor, IC_1 being redeployed to provide a voltage source for its emitter, as in Fig. **1(b)**.

While this circuit worked, it represented little advance in low-level sensitivity; in fact, better results were obtained by removing the collector decoupling and closing the loop around Tr_1 and Tr_2 at rf as in Fig. **2(c)**, which is similar to a circuit which appeared in Ref.1. This offered a useful improvement in low-level sensitivity compared to a simple diode detector. However, the impression was that all these circuit variations were basically more or less complicated ways of extracting such dc output as was obtainable from a basic diode detector circuit.

Back to the diode

My attention was redirected to the shunt diode detector circuit of **Fig. 2(a)**, which conveniently has one end of the diode grounded. The diode dc restores the input rf negative-going with respect to ground, the smoothing circuit then picking out the mean level of the waveform at the diode's anode. Detected dc is thus equal to the peak value of the rf, or would be with an ideal diode, where V_f is zero. The dc detected output of this circuit versus input rf level is the same as the usual diode peak detector circuit of Fig. **2(b)**.

At high levels, the curve is linear, but does not pass through the origin when projected backwards; the detected dc output is not proportional to the rf level. It could be made so by adding a constant offset, equal to V_f, to the detector's output, which would simply have the effect of raising the whole curve by V_f, as in Fig. **2(c)**.

Although the output is now – at least at higher input levels – not only linear but also proportional to the input, there is a standing dc output V_f when no rf is applied. This is an unfortunate state of affairs since V_f is temperature dependent. But with a little lateral thinking, it is possible to add the V_f offset to the detected output in such a way that, as the detected output falls to zero, so does the added offset.

After a few iterations, a circuit designed to do just this finished up with the comparatively simple arrangement of **Fig. 3(a)**. It was built on copper strip-board, except for diode D_1, with R_1, R_2, C_1 and C_2, which were all mounted on the back of a bnc socket, the body of which was soldered to a sheet of copper-clad board. To increase the sensitivity of detector diode D_1, a small amount of forward bias is applied via a 10MΩ resistor R_1, and the resultant offset balanced out by the corresponding drop across D_2. The 2.2MΩ resistor is returned to the positive or negative 15V rail as necessary, depending on whether D_1 or D_2 exhibits the larger forward voltage at the current defined by R_1 and R_6.

These diode voltages are, of course, temperature dependent but, provided they track, they represent purely a common mode signal and IC_{1a} is so connected as to reject any common mode input. Resistor R_2 with C_2 provides the rf smoothing to extract the detected dc component, while R_2 plus R_3 matches the value of the three other bridge resistors R_7, R_8 and R_9.

Op-amp IC_{1a} exhibits an inverting gain of unity to detected output of D_1, and its positive going output is applied to inverting amplifier IC_{1b}, whose gain can be set to a gain of unity, or more or less as required. With the wiper of R_{16} set to ground, the detector law is exactly as in Fig. 3(a).

Positive-going output of IC_{1a} also goes to inverting amplifier IC_{1c}. With R_5 correctly set up, the outputs of IC_{1b} and IC_{1c} will both be zero in the absence of any rf input, at least assuming all the op-amps ideal. With an increasing level of rf applied, the output of IC_{1a} is initially small since it operates in the square-law region, but the output of IC_{1c} will rise much faster as it operates at a gain of 40dB, defined by R_{14}/R_{13}. However, with increasing detector output D_3 starts to conduct, progressively reducing the gain of IC_{1c}. Ultimately, the gain of IC_{1c} falls below unity, indeed almost to zero; in fact, the ratio of the forward resistance of D_3 in the milliamps range (about 20Ω) to

Table 1. Measured performance of test set-up Fig. 4(b).

Input		Output			
dBm		Ideal		Actual	Error
50Ω	mVpk	normalised	mVpk	normalised	%
+20	3180	1.0	3180	1.0	-
+10	1005	0.316	946	0.297	–6
0	318	0.1	299	0.094	–6
–10	101	0.0316	85	0.027	–15
–20	31.8	0.01	31	0.0097	–3
–30	10.1	0.0032	10	0.0031	–1.9
–40	3.2	0.0001	1.3	0.00041	–59

the value of R_{13}, or roughly –40dB.

By advancing the wiper of R_{16} from ground, a proportion of this voltage can be injected into the non-inverting input of IC_{1b}. Note that to an input at its non-inverting input, the gain of IC_{1b} is around 6dB, due to R_{10} and R_{11}+R_{12}. This permits a useful degree of dynamic range extension, by ensuring that the output of the whole circuit starts to rise appreciably at a much lower rf input level than would otherwise be the case.

Test results

I tested circuit operation at rf levels of +20dBm downwards using the set-up in Fig. 3(b), and the results are recorded in Table 1. Originally, I planned to use the video oscillator's maximum output frequency of 10MHz, but the spectrum analyser showed that there was significant second harmonic distortion at this frequency – bad enough to be clearly visible even on the oscilloscope. I therefore carried out the tests at 5MHz, at which frequency the second harmonic was over 35dB down and all other harmonics much lower still. Harmonic distortion – especially even-order distortion – is an important consideration here, as the diode detectors of Figs 3(a) and 4(b) sense the peak of the rf waveform, although the indicated result is conventionally presented as the rms value of the signal. This is assumed to be a pure sinewave.

Generator output at 5MHz was +20dBm using the indication on the spectrum analyser, after setting the gain of the latter using its internal calibration output. As a cross check, I used a newly calibrated oscilloscope to measure the peak-to-peak voltage at the output of the 50Ω through-load, i.e. at the input to the detector circuit. The result was 3.2V pk-pk, perhaps a shade under. This agrees with the expected value of 3.18V pk-pk for +20dB relative to 1mW in 50Ω.

Circuit setup to take the results in Table 1 was as follows. With the wiper of R_{16} at ground and R_{12} set to mid travel, R_5 was adjusted for zero reading on a digital voltmeter. To check that there was negligible hum pick-up, in view of the high circuit gain and the division of the circuit between two different boards, the oscilloscope was also connected to the output of IC_{1c}. A 5MHz +20dBm input was then applied to the 50Ω through-termination and R_{12} adjusted to give the expected theoretical output of 3180mV. Input level was then reduced to –20dBm and R_{16} adjusted to give an output of 31.8mV.

Results were not repeatable, due to the need for frequent resetting of R_5. As a result I relocated D_2 from the circuit board to a position adjacent to D_1, well decoupled to prevent it picking up any rf. The rear of the BNC socket, with the two diodes and related components, was then enclosed in a box, shielding the diodes from both draughts and light. This largely cured the drift problem, although a more modern quad op-amp with improved dc characteristics, in place of the *TL084* used, would be even better.

Following final adjustment of R_5, I repeated the +20dBm and –20dBm adjustments, iterating them alternately until no further adjustment was needed. Later, I took a set of measurements and recorded the results shown in Table 1. Plotting them on log/log

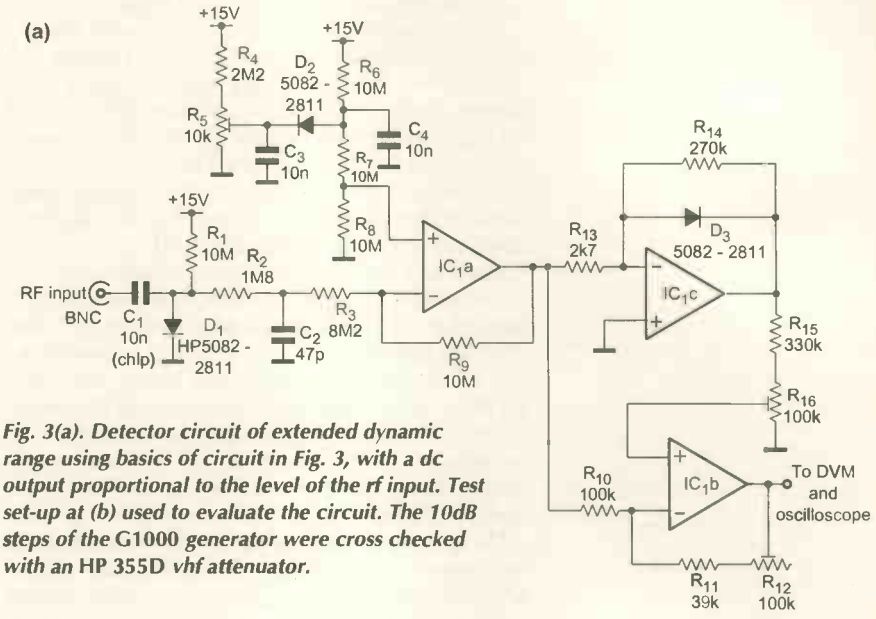
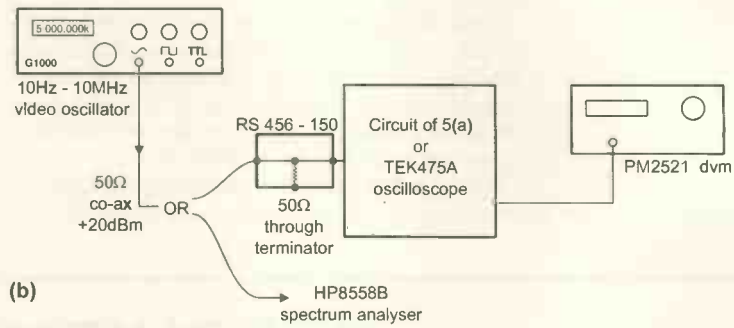


Fig. 3(a). Detector circuit of extended dynamic range using basics of circuit in Fig. 3, with a dc output proportional to the level of the rf input. Test set-up at (b) used to evaluate the circuit. The 10dB steps of the G1000 generator were cross checked with an HP 355D vhf attenuator.



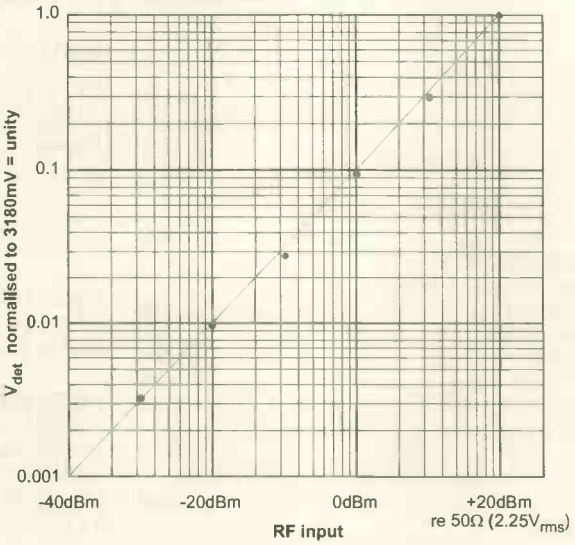


Fig. 4. Results from Table 1 over a 50dB range, plotted on log log graph paper. Vertical axis is actual detected dc output voltage and the horizontal indicates peak input voltage, measured points being indicated on the graph. Sloping line at 45° indicates output that would be provided by perfect detector. For convenience in plotting, both peak input voltage and dc voltage have been normalised to 3.18V (2.25V rms) at unity.

graph paper over a 50dB range gave **Fig.4**.

Results obtained to date are, as can be seen, very encouraging, though certain aspects await further investigation, notably the large negative error at around –10dBm. The three diodes were *HP5082 2811* schottky barrier types intended for general purpose applications. They were not a matched set and were used simply because a number of them were in stock, although they are available as unconnected matched quads under the type number *5082 2815*.

How much improvement using matched diodes would achieve is unknown, as are a number of other possibilities. These include setting up at, say, +20 and –10dBm, instead of +20 and –20dBm, or choosing a different value for the forward bias applied to D_1 and D_2. Other parameters available are varying the ratio of R_{14} to R_{13}, and also their absolute values, and the inclusion of resistance in series with D_3. These might help to reduce the effect of a mismatch between two separate characteristics.

The detector law is a square law at low levels, while the compensation diode law, determining the voltage across D_3, is basically a log law relative to the voltage applied to R_{13}.

Where maximum sensitivity is required from the circuit, one of the low $1/f$ (flicker) noise diodes from the *5082 2xxx* series might be a better choice. For example, the 30V V_{br} of the *5082 2301* would allow the detector to accept inputs up to almost +34dBm against only +27dBm for the *5082 2811*.

For the widest possible dynamic range, the *5082 2800* (*1N5711*) with its V_{br} of 70V would accept an input of up to +40dBm. Assuming that it too would work down to –30dbm in the circuit of Fig. 4(a), it would provide a detector with a dynamic range of over 70dB.

Detectors of wide dynamic range can be used in the linearisation of transmitters using a non-constant envelope type of modulation, e.g. am, dsbsc and all varieties of ssb from compatible am, through pilot carrier types to pure J3E. A negative-feedback loop from the detected audio recovered from a coupler at the transmitter's output, feeding back to the audio input to the exciter, can suppress third-order intermodulation products in a solid state transmitter to 60dB below peak envelope power[2], provided the transmitter is designed to hold am to pm conversion in all stages to a low level. This can provide a much cheaper solution than complex arrangements such as a polar loop or cartesian loop scheme. ■

References

1. Hickman I. *Measuring detectors*, *EW + WW*, November and December, 1991.
2. UK Patent 2209639A, Single Sideband Transmitters, 1991.

RF EQUIPMENT

WIDEBAND AMPLIFIERS
TYPE 9301 100KHz–500MHz. NF 2dB at 500MHz. Gain 30dB. Output 12.5dBm, 18 mW. 50 ohms £175
TYPE 9302 10MHz–1GHz. NF 2dB at 500MHz. Gain 30dB. Output 12.5dBm, 18mw. 50 ohms £175
TYPE 9008 Gasfet. 10MHz–2GHz. NF 2.5dB at 1GHz. Gain 10dB. Output 18dBm, 65mW. 50 ohms £175
TYPE 9009 Gasfet. 10MHz–2GHz. NF 3.8dB at 1GHz. Gain 20dB. Output 20dBm, 100mW. 50 ohms £195

TELEVISION LINEAR POWER AMPLIFIERS
Tuned to your specified channel in bands I, III, IV or V
TYPE 9252 10mW input, 500mW output £390
TYPE 9254 50mW input, 2 watts output £435
TYPE 9259 500mW input, 3 watts output £416
TYPE 9263 2–3 watts input, 12 watts output £700
TYPE 9364 3 watts input, 22–25 watts output £1370
TYPE 9266 10 watts input, 50 watts output. Integral forced air cooling & output transistor protection £2110
TYPE 9367 50 watts input, 150 watts output. Integral forced air cooling & output transistor protection £4345

PULSE TELEMETRY AMPLIFIER
Tuned to your specified frequency in the range 250–470MHz
TYPE 9127 100mW input, 5 watts output £575
TYPE 9128 500mW input, 10 watts output £575

AUTOMATIC TRANSMIT/RECEIVE SWITCHING AMPLIFIERS
Tuned to your specified frequency in the range 400–470MHz
TYPE 9405 100mW input, 5 watts output ..... £775 (Inc. gasfet preamp ..... £960)
TYPE 9406 500mW input, 10 watts output ..... £795 (Inc. gasfet preamp ..... £980)
TYPE 9407 3W input, 25 watts output ..... £895 (Inc. gasfet preamp ..... £1080)

GASFET LNA's 5 MHz – 2 GHz
Two-stage. Masthead or local use.
TYPE 9006 Freq: 5–250MHz. B/W up to 40% of CF. Gain 10–40dB variable. 50 ohms. NF 0.6dB £135
TYPE 9004 Freq: 250–1000MHz. B/W up to 10% of CF. NF 0.7dB. Gain 25dB. 50 ohms £185
TYPE 9305 Freq: 1–2GHz. B/W up to 10% of CF. NF 0.7dB. Gain 20dB. 50 ohms £350
TYPE 9035 Transient protected mains power supply for above preamplifiers £65
TYPE 9010 Masthead weatherproof unit for preamplifiers £18

PHASE LOCK LOOP FREQUENCY CONVERTER
TYPE 9115 Up/down converter. I/p & o/p frequencies 20MHz–2GHz. B/W up to 50MHz. NF 0.7dB. Gain 60dB variable. O/p up to 10mW, +10dBm. AGC £750

PHASE LOCK SIGNAL SOURCES 20–2000 MHz
TYPE 8034 Freq. as specified in the range 20–250MHz. O/p 10mW £250
TYPE 9036 Freq. as specified in the range 250–1000MHz. O/p 10mW £350
TYPE 9038 Freq. as specified in the range 1–2GHz. O/p 10mW £420
TYPE 9282 FM up to ±75KHz max. Freq. as specified in the range 30–2000MHz. O/p 10mW £465

TELEVISION TRANSMISSION MODULES
TYPE 9169 Voltage tunable T/V modulator. Bands I or III or IV or V. O/p 50mW. Sound channel £395
TYPE 9269 PLL T/V exciter. Single channel. Bands I, III, IV or V. O/p 10mW £750
TYPE 9115B PLL T/V transposer. Up to 10 adjacent channels in bands I, III, IV or V. O/p 10mW £750

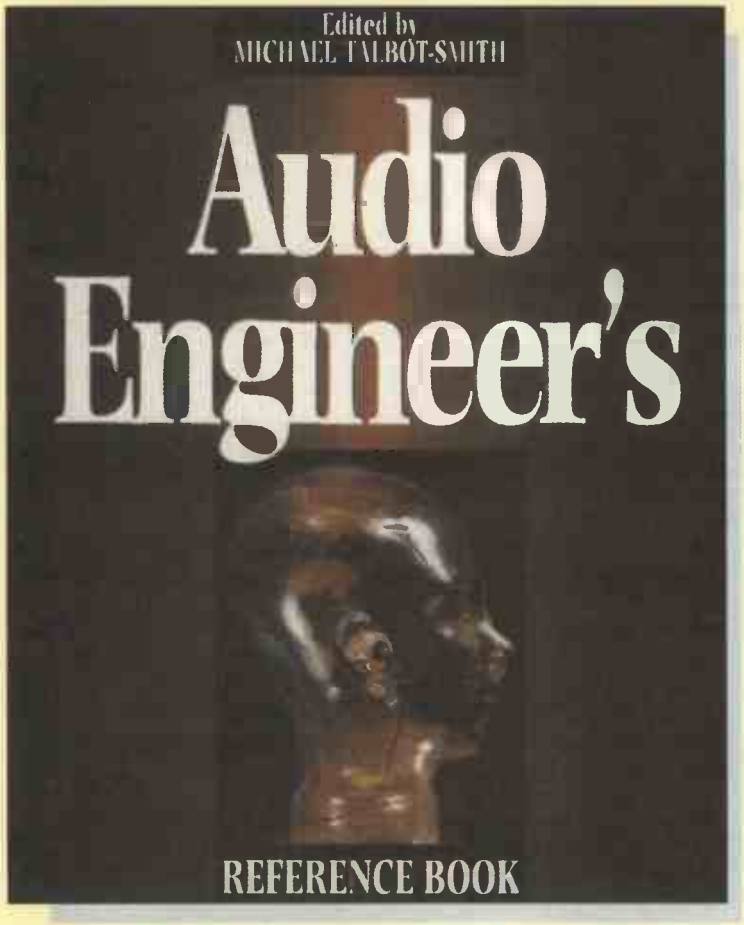
Prices are ex–VAT & ex–P&P.

RESEARCH COMMUNICATIONS LTD
Unit 1, Aerodrome Industrial Complex, Aerodrome Road, Hawkinge, Folkestone, Kent CT18 7AG
Tel: 0303 89 3631 Fax: 0303 89 3838

CIRCLE NO. 111 ON REPLY CARD

Audio Engineer's Reference Book

the work for everyone with a serious interest in audio



- **Comprehensive – over 600 pages**
- **Writen by leading authorities from the audio world**
- **Easy to read, written for maximum accessibility**
- **Concise and authoritative**
- **Covers topics from noise measurement to studio installation**

An invaluable reference work for anyone involved with audio – from broadcast consultant to serious enthusiast.

The Audio Engineer's Reference Book is written by an international team of experts and edited by Michael Talbot-Smith – previously a trainer of audio engineers at BBC Wood Norton and now a freelance audio consultant and technical writer.

Subjects included are:

- Recording, microphones and loudspeakers
- Digital audio techniques
- Basic audio principles
- Acoustics and psychoacoustics
- Audio and television studios and their facilities
- Radio and telephony

Please supply me _____ copies of the AUDIO ENGINEER'S REFERENCE BOOK (ISBN 0 7506 0386 0)
Fully-inclusive price – UK £62.50, Europe £68, Worldwide £78. Please add vat at local rate where applicable.

Business purchase: Please send me the book listed with an invoice. I will arrange for my company to pay the accompanying invoice within 30 days. I will attach my business card/letterhead and have signed the form below.
Guarantee: If you are not completely satisfied, books may be returned within 30 days in a resalable condition for a full refund.

Remittance enclosed £_____
Cheques should be made payable to Reed Business Publishing Group Ltd
Please return to: Jackie Lowe, Room L333, Quadrant House, The Quadrant, Sutton, Surrey, SM2 5AS

Credit card orders accepted by phone. Call 0181 652 8614.

Please debit my credit card as follows:
Access/Master Barclay/Visa Amex Diners

Credit Card No. _____
Exp date
NAME (Please print) _____
ADDRESS _____
_____
_____
_____
POST CODE _____
DATE_____TELE_____

SIGNATURE

VAT RATES
6% Belgium, 25% Denmark, 5.5% France, 7% Germany, 4% Greece, 4% Italy, 3% Luxembourg, 6% Netherlands, 5% Portugal, 3% Spain.
FOR COMPANIES REGISTERED FOR VAT, PLEASE SUPPLY YOUR REGISTRATION NUMBER BELOW (customers outside the EEC should leave this part blank)

VAT NO._____

If in the UK please allow 28 days for delivery. All prices are correct at time of going to press but may be subject to change. Please delete as appropriate. I do/do not wish to receive further details about books, journals and information services.

CIRCUIT IDEAS

SEND YOUR CIRCUIT IDEAS TO THE EDITOR, ELECTRONICS WORLD, QUADRANT HOUSE, THE QUADRANT, SUTTON, SURREY SM2 5AS

Do you have an original circuit idea for publication? We are giving £100 cash for the month's top design. Other authors will receive £25 cash for each circuit idea published. We are looking for ingenuity in the use of modern components.

£100 WINNER

Jump-starting a rom-less microcontroller

Configuring a test clip as shown allows the use of a single sram for both program and data storage by providing a means of loading program code into ram.

With the test clip in place over the ram chip, data reads come from the eprom and writes go to ram and eprom. The following procedure prevents bus contention.

The eprom contains a copy of the required ram data and has a routine at the start which writes 01 to a location 00 in the eprom, then reading it back. If 01 is read, the application code starts, since it now runs from ram without the clip. If not, ram copies the eprom by reading each byte and writing that value back and then stops until the clip is removed and the controller reset. After this procedure, new code can be loaded via the serial port, this code being held in the internal controller ram to avoid overwriting itself. The clip is only then needed in the event of code corruption or a crash.

The system shown uses a Mitsubishi *50747* with the controller and ram permanently powered to avoid the need for ram power-down protection; the controller can use sleep mode. Do not leave i/o pins floating, as that increases current drain. The 1MΩ resistor pack stops the data bus floating.

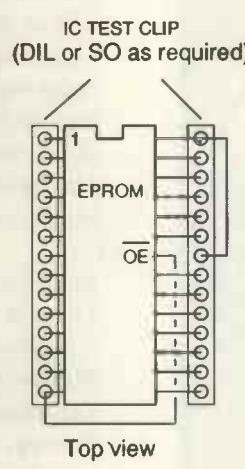


Fig. 1. Wiring of test clip eprom.

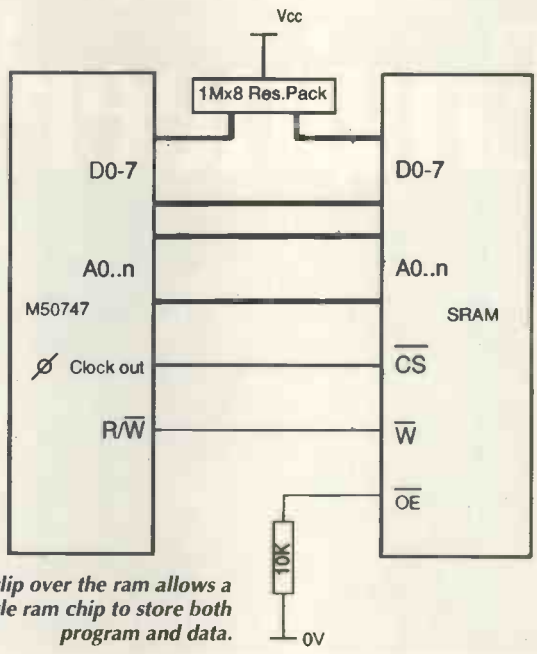


Fig. 2. Using the test clip over the ram allows a microcontroller to use a single ram chip to store both program and data.

Mike Harrison
White Wings Logic
Loughton
Essex

Quadrature-output oscillator for sine waves

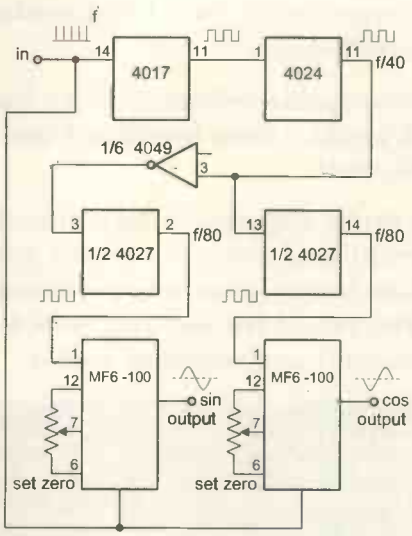
As an alternative to the use of rom look-up tables to generate stored sinusoids, Szymanski[1] described a circuit using steep-cut switched-capacitor filters. In the version shown here, the outputs are two sinusoids at 90° to each other.

Clock signals go straight to the National Semiconductor *MF6-100* switched-capacitor filter, which is a Butterworth low-pass type. After division by 40 in the *4017* decade counter and two stages of the *4024* binary counter, the *f*/40 clock drives two halves of a dual JK bistable device, being inverted to one of them. Inputs to the *MF6*s are now square waves at *f*/80, separated in phase by 90°, and the outputs of the low-pass filters are sinusoids.

Some clock signal appears at the output, but is easily removed by a simple *RC* section without introducing undue phase shift. Improvement can be obtained by increasing the clock division ratio, while ensuring that the last counter stages divide by two.

Harold W Shipton
St Louis
USA

1. EW+WW, July 1994.



Two divider chains, driving switched-capacitor filters, produce sinusoidal outputs at 90° over three decades of f_{in}.

YOU COULD BE USING A 1GHz SPECTRUM ANALYSER ADAPTOR!

Got a good idea? Then this Thurlby-Thandar Instruments TSA1000 spectrum analyser adaptor could be yours.

Covering the frequency range 400kHz to over 1GHz with a logarithmic display range of 70dB ±1.5dB, it turns a basic oscilloscope into a precision spectrum analyser with digital readout calibration.

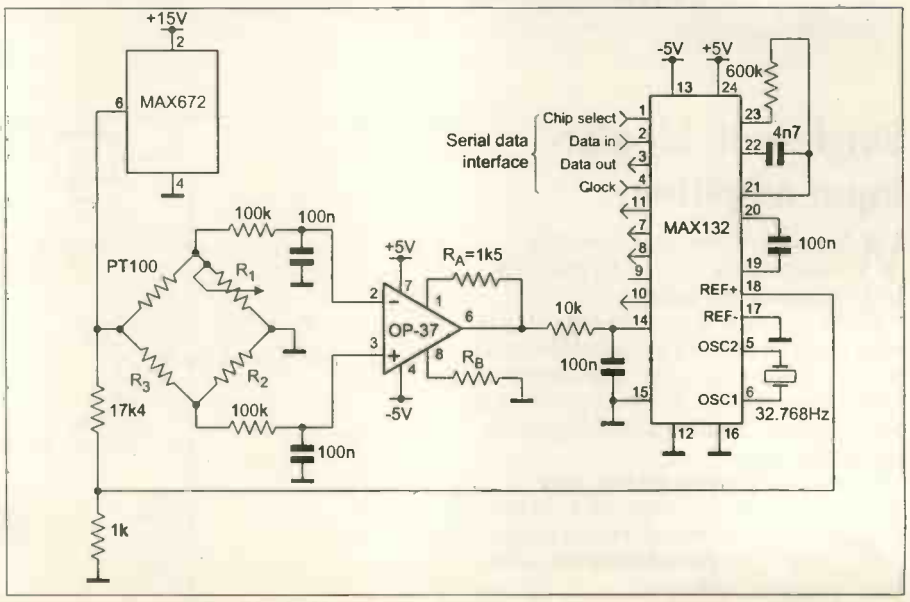
Recognising the importance of good design, **TTI will be giving away one of these excellent instruments every six months** to the best circuit idea published in the preceding period until further notice. **This incentive will be in addition to our £100 monthly star author's fee, together with £25 for all other ideas published.**

Our judging criteria are ingenuity and originality in the use of modern components – with simplicity particularly valued.

Digital thermometer uses low-noise bridge amplifier

To avoid the problem of conventional feedback impairing the low-noise characteristic of an instrumentation amplifier, connect the feedback to the amplifier's trimming pins. The *OP-37* differential amplifier in the circuit shown provides a gain of $3\times10^3/R_B$, resistance R_B being in kilohms, with no effect on noise level. In this case, bridge output is 30mV and the gain to drive the *MAX132* a-to-d converter is 17; R_B is therefore 180Ω.

K Kraus
Rokycany
Czech Republic



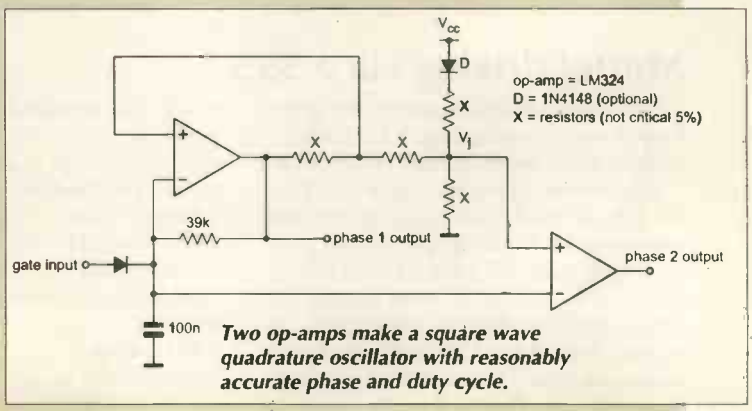
Avoid ruining the noise performance of a differential bridge amplifier by taking the feedback to the trim pins. Circuit shown is a digital thermometer, but the principle applies for any bridge amplifier.

Quadrature oscillator produces square output

Originally intended to drive a stepping motor, this *RC* oscillator produces 90Hz square waves with a 90° phase difference and 1:1 mark:space ratio.

Start operation by taking the gate input low. Diode D compensates for op-amp asymmetry, since the op-amp has the same 5V supply, the mark/space ratio and phase difference being accurate to within about 5%. Frequency is around $0.36/CR$ and is hardly affected by variations in V_{cc}, since all thresholds are proportional to the supply voltage. Voltage V_j varies during the cycle and compensates for the exponential RC charging curve.

W Gray,
Farnborough,
Hampshire



Two op-amps make a square wave quadrature oscillator with reasonably accurate phase and duty cycle.

Active photodiode source

Diode current to a photodiode receiving pulsed infrared signal commonly comes by way of a resistor, as shown in **Fig. 1**. Drawbacks to this simple arrangement are that the resistor shunts signal current, injects thermal noise and may set too low a limit on the current for high light levels.

One solution is to use a gyrator, but it is simpler to use the n-channel fet in **Fig. 2**. Capacitive coupling between source and gate gives the required high ac series impedance and the direct connection between the gate and amplifier input provides bias at any diode current up to I_{ds}.

Corner frequency of the resulting high-pass function is $g_m/2\pi C$, the best hf response being obtained when the load is a low impedance, such as the virtual earth of the *CA3140* fet-input inverting amplifier. Transistor Tr_1 can be a general-purpose n-channel jfet such as a *2N3819*, selected for adequate I_{dss} and maximum pinch-off much less than V_{dg}. Two diodes in the feedback path provide progressive limiting for large signals.

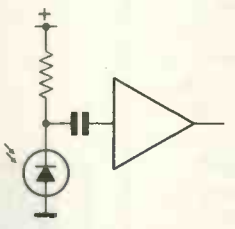


Fig.1. Simple resistive bias to a photodiode may limit diode current at high light levels and inject noise.

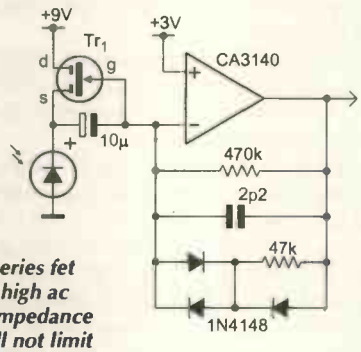


Fig.2. Series fet gives a high ac series impedance and will not limit current.

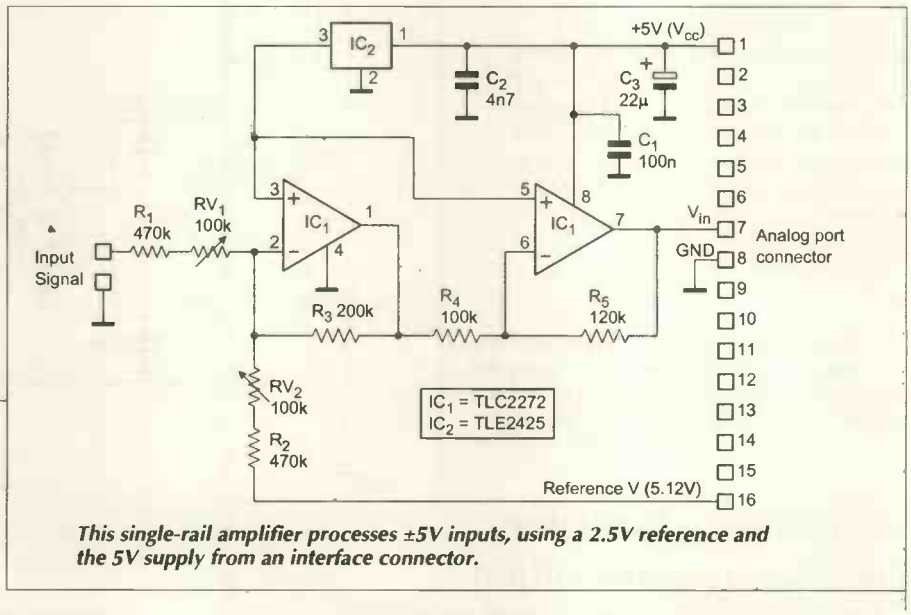
A New
Fishponds
Bristol

Single-rail, bipolar-input amplifier

Without much trouble, an amplifier supplied from only a +5V rail can be made to process ±5V inputs.

A 2.5V reference derived from the 5V rail often found on interface connectors biases the non-inverting inputs of the op-amps. Fixed current through R_2 and RV_2 to the first stage inverting input should be supplied via a stable 5V supply.

To avoid saturation at the first-stage output, gain of the first stage is 0.4, set by RV_1, and 1.2 for the second. Output voltage swings from V_{cc} to ground, using the entire a-to-d converter input range.



This single-rail amplifier processes ±5V inputs, using a 2.5V reference and the 5V supply from an interface connector.

Giorgio Delfitto
University of Padova
Italy

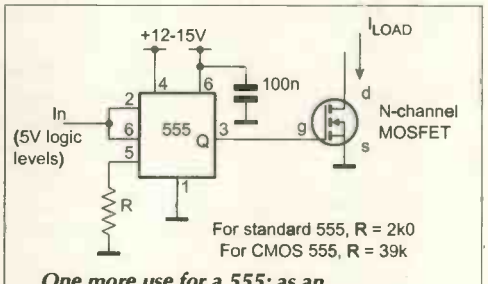
Mosfet driving via a *555*

If you need to drive one mosfet and have a space-saving requirement, a *555* timer replaces half a dozen discrete components.

If the mosfet supply lies within 12-15V, the timer drives the gate to at least 10V and, because of the *555* totem-pole output, switching on and off takes 100ns or less.

Input impedance to the timer is high, output impedance low and setting the voltage on pin 5 to +3.5V by R ensures level conversion from 5V logic to that needed by the mosfet gate. Pin 4 is the reset input, which can, if required, be used for an inhibit input. For pulse control of the mosfet, configure the *555* as a free-running or monostable flip-flop.

Supply voltage for cmos *555*s should be 14V or less and switching speed may be slightly reduced. Decouple the timer supply close to the chip and mount the device near the mosfet.



One more use for a 555: as an inverting gate driver and level shifter for mosfets.

S H Dolding
Carlingford
NSW, Australia

Preventing battery over-discharge

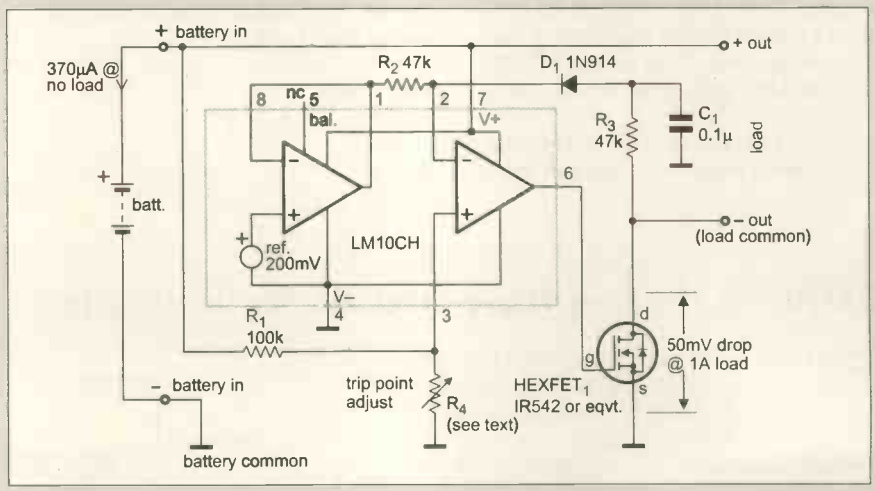
To prevent failure of rechargeable batteries from over-discharging, this circuit switches the load out of circuit at a preset battery voltage. Depending on Hexfet type, it handles loads of over 20A, needs no heat sink and in a no-load condition takes only 370µA.

An *LM10CH* contains an op-amp, buffer and voltage reference. The buffered reference is taken via R_2 to the op-amp, which is used to compare the reference with the fraction of battery voltage set by $R_{1,4}$, its output switching the Hexfet on and off.

If battery voltage falls below the trip point which, for 12V cells, is about 10.5V, the fet switches off and the negative output terminal rises towards the battery voltage, latching itself off through R_3, D_1, C_1 and the comparator. If the battery voltage increases after the load is removed, the switch stays off due to the voltage through D_1 from the rail. If either the load or battery is removed and reconnected, the circuit restarts if the battery voltage is above the trip point.

V Labuc
Hudson
Quebec, Canada

Switching circuit avoids damage to rechargeable cells, which must not be allowed to discharge to below a given terminal voltage. Circuit handles over 20A load.



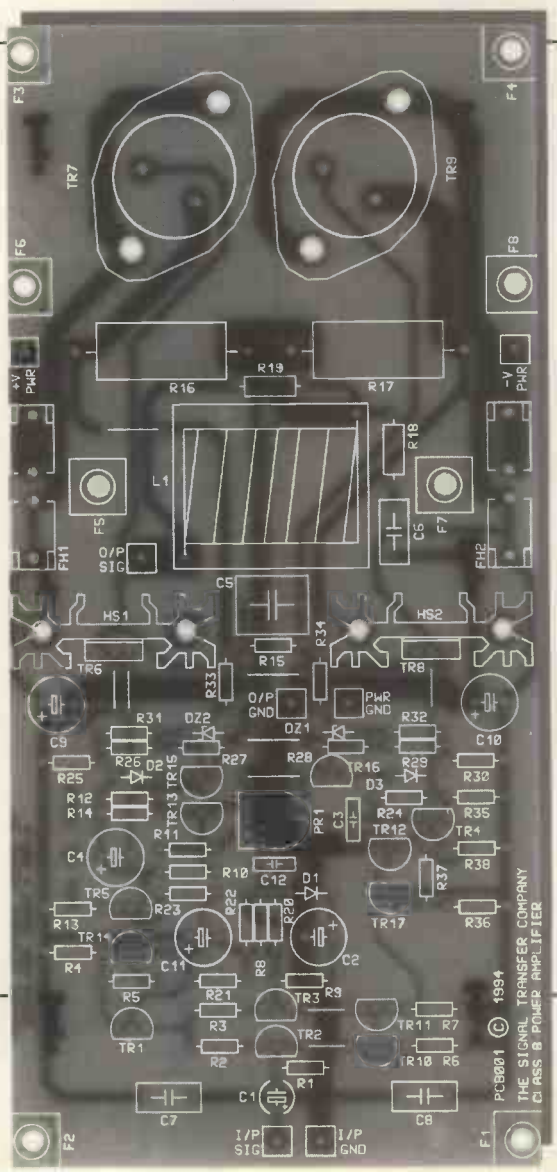
PCBs for Douglas Self's power amplifier series

Circuit boards for Douglas Self's high-performance power amplifier are now available via *EW+WW*.

Detailed on page 139 of the February 1994 issue, Douglas Self's state-of-the-art power amplifier is the culmination of ideas from one of the most detailed studies of power amplifier design ever published in a monthly magazine. Capable of delivering up to 100W into 8Ω, the amplifier features a distortion of 0.0015% at 50W and follows a new design methodology.

Designed by Douglas himself, the fibreglass boards have silk-screened component IDs and solder masking to minimise the possibility of shorts. Sold in pairs, the boards are supplied with additional detailed constructional notes.

Each board pair costs £45, which includes VAT and postage, UK and overseas. Credit card orders can be placed 24 hours on 081-652 3614. Alternatively, send a postal order or cheque made payable to Reed Business Publishing to EW+WW, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS.

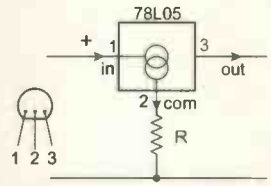


Tricks with a voltage regulator

It is worth pointing out that between the input and common pins of a Motorola *7805ACP* 5V voltage regulator is a useful current regulator. A batch of these devices showed a current of 2mA regardless of the applied voltage over 7V or load. A *TI8306* (*78L05*) still had the constant current, but of 3.5mA.

To increase the output of the IC regulator, one can insert a diode in the common leg but, in view of the constant current of 2mA, a resistor of 500Ω/volt is satisfactory. There seems to be no loss of conventional regulator performance when the *7805* is used in these ways.

John Cronk
Prestatyn
Clwyd
Wales



Unorthodox use of a Motorola 7805 voltage regulator to obtain a current regulator and to increase voltage output.

Driving three-phase brushless dc motors

Figure 1 shows a circuit designed to test the functioning of a range of three-phase brushless motors obtained from disk drives.

A *4018* divide-by-*n* counter generates the three-phase drive waveforms[1] shown in Fig. 2, feedback from Q_3 causing the first three Johnson counters to generate a six-step sequence, which is sequentially stepped out via Q_4 and Q_5. Waveforms from Q_1, Q_3 and Q_5 each take six clock pulses per cycle, the phase lags being 120°.

Direction control is provided by an input to the *4070* Ex-Or, which inverts phases 1 and 2 when the input is high, and the *4001* simply switches off the motor drive transistors by grounding their gates.

N-channel *IR 110* mosfets rated at an amp were used in the prototype, but for higher current, Fig. 3 shows a circuit using *TIP 122* Darlingtons.

Motors tested appeared to be rated at 24V, 2A, and maximum clock frequency was 200Hz, giving a motor speed of 2000rev/min. At very low clock frequencies – 2Hz – the motor stutters before rotating smoothly, an effect that disappears at higher speeds.

W A Russell
Bay of Plenty Polytechnic
Tauranga
Australia

Reference

1. Lancaster D. *Cmos Cook Book*, 2nd edition.

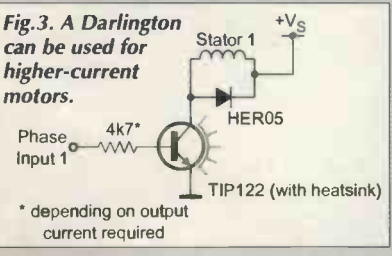


Fig.3. A Darlington can be used for higher-current motors.

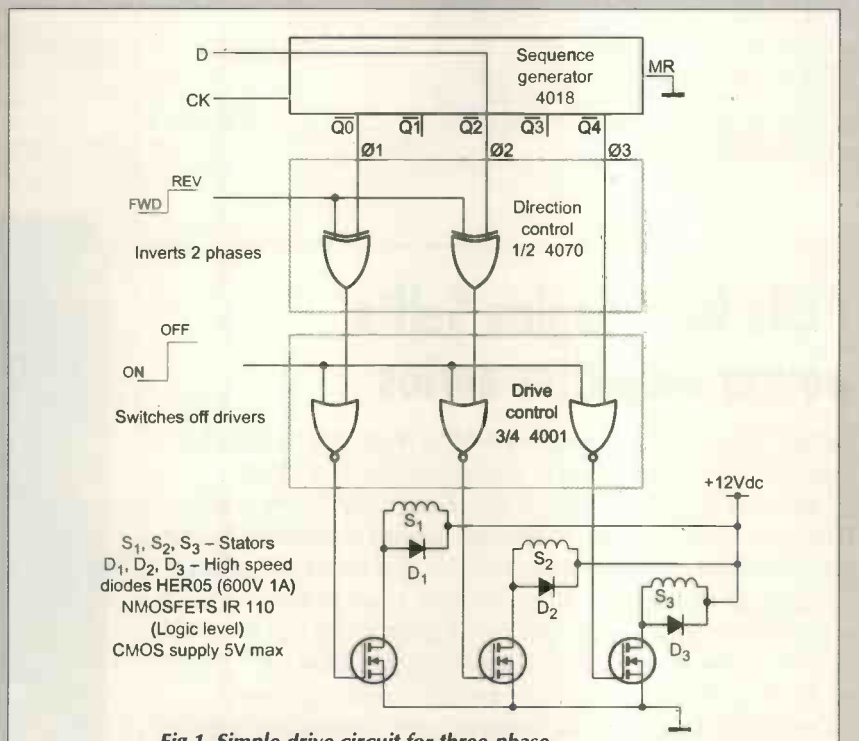


Fig.1. Simple drive circuit for three-phase, brushless dc motors, with reverse and inhibit inputs.

Q0	Q1	Q2	Q3	Q4
1	0	0	1	1
1	1	0	0	0
1	1	1	0	0
0	1	1	1	0
0	0	1	1	1
0	0	0	1	1
1	0	0	0	1
1	1	0	0	0
1	1	1	0	0
0	1	1	1	0
0	0	1	1	1
0	0	0	1	1

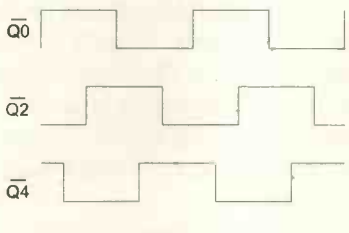


Fig.2. Drive waveforms from circuit of Fig.1.

LOUDSPEAKERS

2" Round 50 ohm Coil ½W, 2 for **£1**, Order Ref: 908.
2¼" 8 ohm, 2 for **£1**, Order Ref: 454.
2½" 35 ohm, 2 for **£1**, Order Ref: 514
2½" 8 ohm, 2 for **£1**, Order Ref: 682.
6½" 4 ohm with Tweeter, £1, Order Ref: 895.
6½" 6 ohm, £1, Order Ref: 896.
6½" 8 ohm with Tweeter, £1, Order Ref: 897.
6" x 4" 4 ohm, £1, Order Ref: 242.
5" x 5" 15 ohm, £1, Order Ref: 906.
5" x 5" 16 ohm, £1, Order Ref: 725.
6" x 4" 16 ohm, 2 for **£1**, Order Ref 684.
8" 15 ohm Audax, £1, Order Ref: 504.
9" x 3" 8 ohm 5W, £1, Order Ref: 138.
3" 4 ohm Tweeter, £1, Order Ref: 433.
Goodmans 6½" 10W 4 ohm, £2, Order Ref: 2P27.
Horn Speaker 4½" 8 ohm, £3, Order Ref: 3P82.
20W 5" 4 ohm by Goodmans, £3, Order Ref: 3P145.
20W 4" 4 ohm Tweeter, £1.50, Order Ref: 1.5P9.
Amstrad 8" 15w 8 ohm with matching Tweeter. **£4**, Order Ref: 4P57.
Cased pair of Stereo Speakers by Bush, 4 ohm, £5 per pair, Order Ref: 5P141.
Double Wound Voice Coil, 25W ITT with Tweeter and Crossover, **£7**, Order Ref: 7P12.
25W 2 way Crossover, 2 for **£1**, Order Ref: 22.
40W 3 way Crossover, £1, Order Ref: 23.

MAINS TRANSFORMERS

5V 45A, £20, Order Ref: 20P16.
6V 1A, 2 for **£1**, Order Ref: 9.
8V 1A, £1, Order Ref: 212.
9V ½A, 2 for **£1**, Order Ref: 266.
9V 1A, £1, Order Ref: 236.
10V 1A, £1, Order Ref: 492.
12V ½A. 2 for **£1**, Order Ref: 10.
12V 1A, £1, Order Ref: 436.
12V 2A, £2, Order Ref: 2P337.
15V 1A, £1, Order Ref: 267.
17V 1A, £1, Order Ref: 492.
18V ½A, £1, Order Ref: 491.
20V 4A, £3, Order Ref: 3P106.
24V ½A, £1, Order Ref: 337.
30V 2½A, £4, Order Ref: 4P24.
36V 3A, £3, Order Ref: 3P14.
40V 2A, £3, Order Ref: 3P107.
43V 3½A, £4, Order Ref: 4P14.
50V 2A fully shrouded, **£5**, Order Ref: 5P210.
50V 15A, £20, Order Ref: 20P2.
90V 1A, £4, Order Ref: 4P39.
675V 100mA, £5, Order Ref: 5P166.
3kV 3mA, £7, Order Ref: 7P7.
4kV 2mA, £5, Order Ref: 5P139.
6-0-6V 10VA, £1, Order Ref: 281.
8-0-8V 8VA, £1, Order Ref: 212.
12-0-12V 2V 3VA, £1, Order Ref: 636.
12-0-12V 6VA, £1, Order Ref: 811.
12-0-12V 50VA, £3.50, Order Ref: 3.5P7.
15-0-15V 1VA, £1, Order Ref: 937.
15-0-15V 15VA, £2, Order Ref: 2P68.
18-0-18V 10VA, £1, Order Ref: 813.
20-0-20VA 10VA, £1, Order Ref: 812.
20-0-20V 10VA, £2, Order Ref: 2P85.
20-0-20V 20VA, £2, Order Ref: 2P138.
20-0-20V 80VA, £4, Order Ref: 4P36.
36-0-36V 20VA, £2, Order Ref: 2P156.

SPECIAL TRANSFORMERS

15VA gives 1V, 7V, 8V, 9V or 10V, **£1**, Order Ref: 744.
38-0-38V 15VA with regulator winding, **£10**, Order Ref: 10P36.
230V-115V auto transformer 100VA, **£2**, Order Ref: 2P6.
230V-115V auto transformer 10VA, **£1**, Order Ref: 822.
230V-115V auto transformer 1kVA, **£20**, Order Ref: 20P29.
MULTI VOLTAGE auto transformer, gives 115V and voltages above and below this. **£4**, Order Ref: 4P79.

ISOLATION TRANSFORMERS

230V-230V 10VA, £1, Order Ref: 821.
230V-230V 150VA, £7.50, Order Ref: 7.5P5.
440V-240V 220VA, £10, Order Ref: 10P115.

MISCELLANEOUS BARGAINS

We have approximately 2,000 various bargains available. We cannot possibly list them all on this page. Most of those we have previously advertised are still available. If there is anything you especially want, then please give us a ring.

DC MOTOR SPEED CONTROLLER
Now available made up, cased and tested. Two versions, one for motors up to ¼hp, **£29.50**, Order Ref: 29.5P2, and a more powerful model suitable for motors up to ½hp is **£37.50**. Order Ref: 37.5P1. Still available in kit form, **£18.**, Order Ref: 18P8, and **£26**, Order Ref: 26P1.

⅓rd HORSE POWER 12V MOTOR
(Sinclair C5) **£29.50**, Order Ref: 29.5P1.

0V-20V DC PANEL METER
This is a nice size 65mm sq. It is ideal if you are making a voltage variable instrument or battery charger. Price **£3**, Order Ref: 3P188.

FLASHING BEACON
Ideal for putting on a van, a tractor or any vehicle that should always be seen. Uses a XENON tube and has an amber coloured dome. Separate fixing base is included so unit can be put away if desirable. Price **£7.50**, Order Ref: 7.5P13.

ANOTHER 12V-0V-12V TRANSFORMER is a 50VA and is suitable for dropping through the chassis or as it is fitted with 4 pillars it can be mounted above the chassis. Also should you want a 12V 4A transformer then this one should be quite suitable, you use just one half of the secondary. Price **£3.50**, Order Ref: 3.5P7.

HIGH RESOLUTION MONITOR
9" by Philips, in metal frame for easy mounting. Brand new, offered at less than price of tube alone, only **£15**, Order Ref: 15P1.

15W 8" 9 OHM SPEAKER & 3" TWEETER
Amstrad, made for their high quality music centre, **£4** per pair, Order Ref: 4P57.

INSULATION TESTER WITH MULTIMETER
Internally generates voltages which enables you to read insulation directly in megohms. The multimeter has four ranges, AC/DC volts, 3 ranges milliamps, 3 ranges resistance and 5 amp range. These instruments are ex-British Telecom but in very good condition, tested and guaranteed OK, probably cost at least £50, yours for only **£7.50** with leads, carrying case **£2** extra, Order Ref: 7.5P4.

WE HAVE SOME of the above testers but slightly faulty, not working on all ranges, should be repairable, we supply diagram, **£3**, Order Ref: 3P176.

250W LIGHT DIMMER
Will fit in place of normal wall switch, only **£2.50** each, Order Ref: 2.5P9. Note these are red, blue, green or yellow but will take emulsion to suit the colour of your room. Please state colours required.

TOUCH DIMMERS
40W-250W, no knob to turn, just finger on front plate will give more or less light, or off. Silver plated on white background, right size to replace normal switch, **£5**, Order Ref: 5P230.

LCD 3½ DIGIT PANEL METER
This is a multi-range voltmeter/ammeter using the A-D converter chip 7106 to provide 5 ranges each of volts and amps. Supplied with full data sheet. Special snip price of **£12**, Order Ref: 12P19.

MULTI TESTER
19 range, ex-British Telecom, reconditioned. These measure AC and DC volts, DC milliamps and have 3 resistance ranges made to BT specification and 20,000 opv movement. Complete with test prods, **£8.50**, Order Ref: 8.5P3. Carrying case with handle **£2** extra.

CLOCK MODULE
2" LCD display, requires 1.5V battery, goes back to zero when switched off so ideal for timing operations, **£2**, Order Ref: 2P307.

MINI BLOW HEATER
1kW, ideal for under desk or airing cupboard, etc. Needs only a simple mounting frame, **£5**, Order Ref: 5P23.

MEDICINE CUPBOARD ALARM
Or it could be used to warn when any cupboard door is opened. The light shining on the unit makes the bell ring. Complete built and neatly cased, requires only a battery, **£3**, Order Ref: 3P155.

DON'T LET IT OVERFLOW!
Be it bath, sink, cellar, sump or any other thing that could flood. This device will tell you when the water has risen to the pre-set level. Adjustable over quite a useful range. Neatly cased for wall mounting, ready to work when battery fitted, **£3**, Order Ref: 3P156.

FIGURE 8 FLEX
A wire with a thousand uses. It will carry 5A and is insulated up to 300V but is thin enough to hide away along the carpet or skirting. Also ideal for burglar alarms, door bells, etc, etc. 50m coil **£2**, Order Ref: 2P345.

£1 BARGAIN PACKS – LIST 2

This is the £1 Bargain Packs List 2 – watch our for lists 3 and 4 next month.

3 x Battery Model Motors, tiny, medium and large, Order Ref: 35.
2 x Tuning Capacitors for medium wave radios, Order Ref: 36.
Miniature 12V Relay with low current consuming coil, **2 x** 3A changeover contacts, Order Ref: 51.
2 x Ferrite Slab Aerials with medium wave coils. Ideal for building small radio, Order Ref: 61.
2 x 25W 8 ohm Variable Resistors. Ideal for loudspeaker volume control, Order ref: 69.
2 x Wirewound Variable Resistors in any of the following values, 18, 35, 50, 100 ohms, your choice, Order Ref: 71.
4 x 30A Porcelain Fuse Holders. Make your own fuse board, Order Ref: 82.
2 x 6½" Metal Fan Blades for 5/16" shaft, Order Ref: 86/6½.
Mains Motor to suit the 6½" blades, Order Ref: 88.
1 x 4.5V 150mA DC Power Supply. Fully enclosed so quite safe, Order Ref: 104.
10 each red and black small size Crocodile Clips, Order Ref: 116.
15m Twin Wire, screened, Order Ref: 122A.
100 Plastic Headed Cable Clips, nail in type, several sizes. Order ref: 123.
4 x MES Batten Holders, Order Ref: 126.
Complete Pocket Size MW Radio, believed OK but not tested, Order Ref: 133R.
4 x 2 Circuit Micro Switches (Licon) Order Ref: 157.
1 x 13A Switch Socket, quite standard but coloured, Order Ref: 164.
1 x 30A Panel Mounting Toggle Switch, double-pole, Order Ref: 166.
2 x Neon Numicator Tubes, Order Ref: 170.
100 x ⅜ Rubber Grommets, Order Ref: 181.
6 x BC Lamp Holder Adaptors, Order Ref: 191.
8 x Superior Type Push Switches. Make your own keyboard, Order Ref: 201.
Mains Transformer 8V-0V-8V ½A, Order Ref: 212.
2 x Sub Min Toggle Switches, Order Ref: 214.
High Power 3" Speaker (11W 8ohm) Order Ref: 246.
Medium Wave Permeability Tuner, it's almost a complete radio with circuit, Order Ref: 247.
6 x Screwdown Terminals with through panel insulators, Order Ref: 264.
LCD Clock Display, ½" figures, Order Ref: 329.
10 x Push-on Long Shafted Knobs for ¼" spindle, Order Ref: 339.
2 x ex-GPO Speaker inserts, ref 4T, Order Ref: 352.
100 x Sub Min 1F Transformers. Just right if you want coil formers, Order Ref: 360.
1 x 24V 200mA PSU, Order Ref: 393.
1 x Heating Element, mains voltge 100W, brass encased, Order Ref: 8.
1 x Mains Interference Suppressor, Order Ref: 21.
3 x Rocker Switches, 13A mains voltage, Order Ref: 41.
1 x Mini Uni-Selector with diagram for electronic jigsaw, Order Ref: 56.
2 x Appliance Thermostats, adjustable up to 15A, Order Ref: 65.
1 x Mains Motor with gearbox giving 1 rev per 24 hrs, Order Ref: 89.
10 x Round Pointer Knobs for flatted ¼" spindles, Order Ref: 295.
1 x Ceramic Wave Change Switch, 12-pole, 3-way with ¼" spindle, Order Ref: 303.
1 x Tubular Hand Mike, suits cassette recorders, etc. Order Ref: 305.
2 x Plastic Stethosets, take crystal or magnetic inserts, Order Ref: 331.
20 x Pre-set Resistors, various types and values, Order Ref: 332.
6 x Car Type Rocker Switches, assorted, Order Ref: 333.
10 x Long Shafted Knobs for ¼" flatted spindles, Order Ref: 339.
1 x Reversing Switch, 20A double-pole or 40A single-pole, Order Ref: 343.
4 x Skirted Control Knobs, engraved 0-10, Order Ref: 355.
3 x Luminous Rocker Switches, Order Ref: 373.
2 x 1000W Tubular Heating Elements with terminal ends, Order Ref: 376.
1 x Mains Transformer Operated NICad Charger, cased with leads, Order Ref: 385.
2 x Clockwork Motors, run for one hour. Order Ref: 389.

Prices include VAT. Send cheque/postal order or ring and quote credit card number.
Add £3 post and packing
Orders over £25 post free.

M&B ELECTRICAL SUPPLIES LTD
Pilgrim Works (Dept. WW), Stairbridge Lane, Bolney, Sussex RH17 5PA
Telephone (01444) 881965 – (Also Fax but phone first)
Callers to 12 Boundary Road, Hove, Sussex

CIRCLE NO. 119 ON REPLY CARD

Improving analogue conversion

Getting the best high frequency performance from a clocked d-to-a converter normally needs a complex post-conversion filter designed using cad. Michael Batty's sin(x)/x correction filter provides an easy to implement yet effective means of compensating for a clocked data converter's natural roll off.

Most d-to-a converters are effectively sample and hold devices. They latch each successive incoming value to provide a first-order 'staircase' approximation of the output signal.

Conversion is normally followed by a low-pass reconstruction filter. This is typically a high-order elliptic design giving a relatively flat response up to just below half the sampling frequency, F_s, followed by a sharp cut-off. But this arrangement provides no correction for the sinc function (sin(x)/x) fall-off in amplitude naturally produced by the sample and hold function.

As shown in **Fig. 1**, the roll off reaches the considerable value of –3.9 dB at $F_s/2$, falling to zero at F_s. Correction for this roll off can be designed into the reconstruction filter if computer-aided design tools are available, but the simple separate correction filter described here yields excellent results and allows more flexible design.

The correction filter is a simple second-order low-pass section, with frequency and Q optimised to have a response almost exactly inverse to that of the sinc roll off function up to around $0.4F_s$. If required, a single additional second-order all-pass stage can be cascaded to improve delay equalisation of the correction filter.

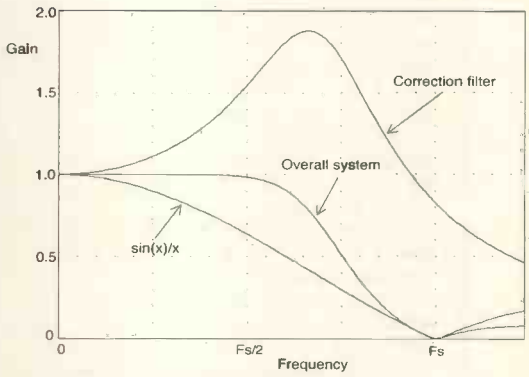


Fig. 1. Amplitude correction scheme uses a filter with a response which is almost exactly complementary over a wide range of frequency to the sin(x)/x roll off inherent in the d-to-a converter. This cancels the roll off to a surprising degree of accuracy, considering the simplicity of the scheme, although the response deviates markedly above half the sampling frequency. However, by this stage, the stopband response of the normal analogue reconstruction filter should give adequate rejection.

Note that in most practical situations, the delay equalisation stage may be omitted, since it is unlikely that the accompanying reconstruction filter will itself have linear phase. Also, the correction filter alone is *not* useful as a reconstruction filter, due to its rather poor roll off characteristics.

Figure 2 shows the general configuration of the correction scheme, with optimised filter parameter values. Frequency and Q for each stage were arrived at by a simple but partly computer-assisted optimisation procedure, with a goal of maximum flatness and linear phase up to $0.4F_s$.

Results are shown in **Fig. 3**. The low-pass stage produces a surprisingly flat equalisation of the sinc function: to within ±0.01 dB from

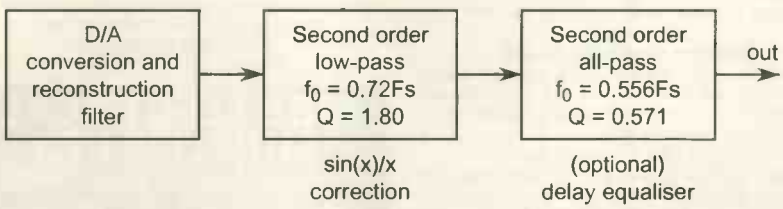


Fig. 2. Amplitude correction and optional delay correction stages are simply cascaded at the output of the d-to-a converter. These two stages consist of second-order low-pass and all-pass filters respectively, with parameters as shown. The delay correction stage should only be needed if it is desired to approximate linear phase (constant delay) behaviour from the whole system.

0 to $0.4F_s$, with an error of –0.12 dB at $0.5F_s$. The optional delay equalisation stage results in an overall phase linearity to within ±0.5° from 0 to $0.4F_s$, or a group delay variation of less than ±0.7% within this range. In practice these figures will almost certainly be swamped by analogue component tolerances.

Figure 4 shows a practical implementation for an F_s of 20kHz using single op amp stages, quite adequate for the low Qs involved, although the choice of op amp may depend on the value of F_s if high accuracy is required. In any case precise components of 1% tolerance or better should be used.

Preceded by a unity-gain buffer stage to provide a low source impedance, the low-pass section uses a standard unity-gain Sallen and Key design. The optional delay equaliser section includes a final gain stage to compensate for 12.2dB loss in the all-pass stage. Component values in the two filter stages may of course be modified for other values of F_s by scaling either resistor or capacitor values in the standard manner. ■

Further reading

Analog filter design by M. E.Van Valkenburg, 1982, Sect. 6.5, 18.4, pub. Holt Rinehart & Winston.

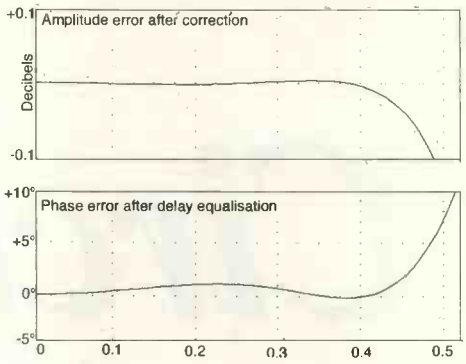


Fig. 3. Residual amplitude ripple is extremely small by most standards, and would suit, for example, instrumentation applications such as digital waveform generators. With the optional delay correction, the residual phase deviation from linear behaviour is also fairly small (less than 0.5° up to 0.4 times F_s). In reality, it is likely that real component tolerances will introduce larger variations than these.

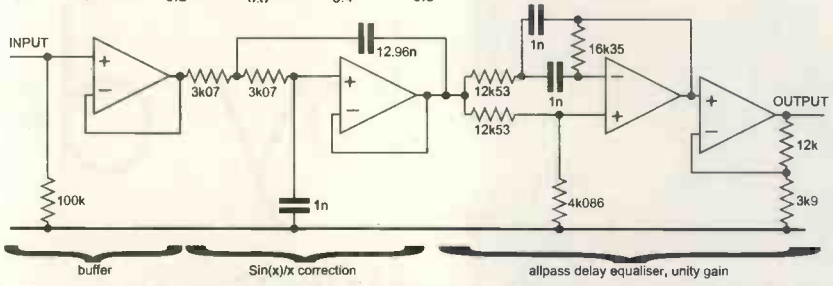


Fig. 4. The correction scheme may be realised at audio frequencies using simple second-order op-amp filter circuits, this diagram showing a practical circuit designed for a sampling frequency of 20kHz. For precision applications a full circuit simulation is suggested, to examine the effects of passive component tolerances and real op-amp limitations. For other sampling frequencies, all R (or C) values in the second and third op-amp stages may be scaled inversely with frequency in the usual way. Details of the all-pass filter design may be found in the reference.

D-to-a converters and sin (*x*)/*x* roll off

Spectral roll off produced by a d-to-a converter which always holds (latches) its last value is a well known effect in signal processing systems, and may be briefly (although by no means trivially) understood as follows:

Prior to sampling, a signal spectrum can consist of frequency components up to half the sampling frequency, F_s, as shown in **Fig. A** (if they are any higher we run into undersampling and hence aliasing problems – another issue).

Ideally, sampling a signal can be quite correctly considered as multiplying it by a train of impulses, **Fig. B**, thus producing a spectrum containing an infinite number of copies of the signal band, each symmetrically 'folded' about harmonics of the sampling frequency. This may perhaps be understood more simply in the frequency domain by considering sampling as a mixing process; the various copies of the spectrum formed correspond to all the sum and difference products formed by the signal and the uniform comb of harmonics of the sampling signal.

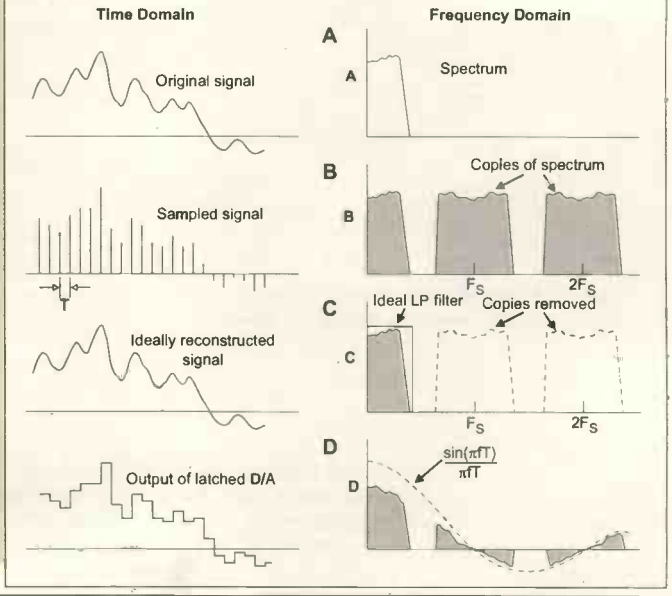
To accurately reconvert the signal into analogue form, it must, of course, be smoothed; this is just equivalent to low-pass filtering. In the frequency domain, this reconstruction filter does its job perfectly if it removes all copies of the spectrum except the one near zero frequency, as shown in **Fig. C**. The analogue signal is then perfectly recovered. Clearly, an ideal reconstruction filter would have zero attenuation (and phase shift) up to $0.5F_s$, but infinite loss above this.

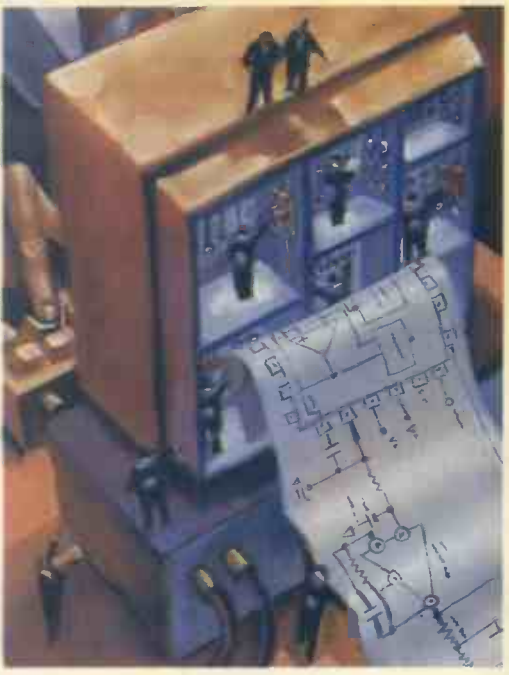
The effect of holding the last output of a d-to-a converter is to provide a degree of (stepwise) smoothing, which does give some low-pass filtering, but is far from ideal. At this point, we need a little signal processing theory to help. In the time domain, the hold function is equivalent to convolving the sampled waveform with a rectangle function of width one sampling period. Now Fourier theory (in particular the convolution theorem) tells us that in frequency terms, this is exactly equivalent to multiplying the spectrum by the Fourier Transform of the rectangle function, which just happens to be of the form:

$$\frac{\sin(\pi fT)}{\pi fT}$$

(commonly known as a sin*c* function), where f is the frequency and T the sampling period, $1/F_s$). This is illustrated in **Fig. D**, and produces a zero value at F_s, with a –3.9dB response at $0.5F_s$, thus distorting the spectrum considerably from the original. Clearly if the sampling frequency is very high compared to the signal (ie highly oversampled), then the effect on the signal may be small, and this is often used to advantage.

Spectra illustrating the need for sin(x)/x corrective filtering.





Circuits by design

4: Filters

Due to the number of calculations involved, filter design in particular is greatly simplified by using cad software. Owen Bishop describes how to get the best out of modern circuit simulation and analysis tools.

A first-order low-pass passive filter is easily realised with a pair of components, **Fig. 1**, or as a Spice netlist, **Fig. 2**. With the selected values of the capacitor and resistor, the –3dB point – cut-off frequency – is $f_c = 1/2\pi RC = 1592$Hz. I will use this simple example to demonstrate some of the frequency response analyses available in *SpiceAge for Windows*. For all of these analyses, a voltage probe is set between 'vout' and 'gnd', so that it monitors voltage across the capacitor.

The first run is a straightforward Bode Plot, input being a 1kHz sine wave at 1V. Frequency range is set for 10Hz to 1MHz in 100 steps. Under the Frequency drop-down menu, select Y-display mode, then tick dB plot and Phase plot.

Under Analyse, selecting Frequency response now produces **Fig. 3**. On the left is a decibel scale, instead of the usual voltage scale, with 0dB being equivalent to 1V, the amplitude of the voltage generator. On the right is a phase scale running from +180° to –180°.

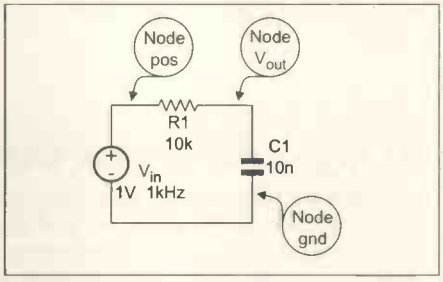


Fig. 1. Nodes of this simple low-pass filter are named, ready for entering in as a SpiceAge netlist.

The graph has two curves, one for output signal amplitude and the other – in a different colour on the display – for the phase difference between the input and output signals. The graphs show that amplitude begins to fall above about 50Hz.

The cross-hairs are placed on the –3dB point, as indicated by the value displayed below the graph. At this point the frequency

```
* CBD04 - Low-pass passive RC filter, 1.6kHz
V Vin       -out:gnd    +out.pos    v=1.000000  Ex=Sine  Fr=1.00000k
R R1        p1:pos      p2:vout     v=10.0000k
C C1        p1:vout     p2:gnd      v=10.0000n
```

Fig. 2. The netlist above defines the values of the components in Fig. 1, and the connections between them.

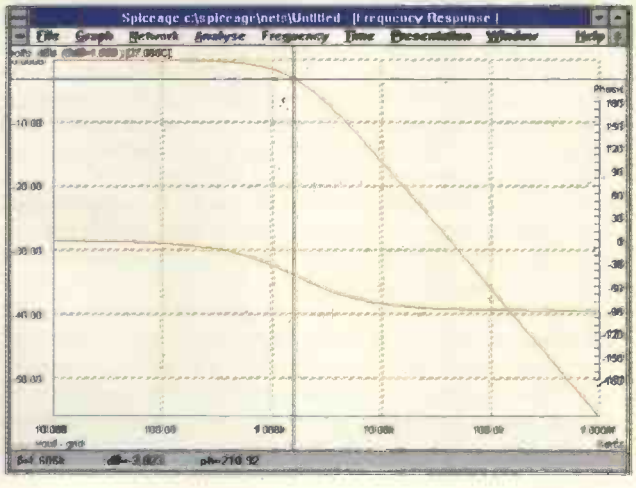


Fig. 3. A frequency sweep shows a typical low-pass amplitude curve, right. Phase of the output signal lags when frequency is greater than about 1kHz, tending toward 90° as frequency approaches 1MHz.

reading is 1.606kHz, which is the closest reading to the calculated value of f_c. Beyond this point, response falls steadily at –6dB per octave.

Phase changes are shown on the lower curve. At low frequencies, the output signal is in phase with input. As frequency increases, the output lags further and further behind input, eventually finishing with a phase lag of 90°.

Another display mode, **Fig. 4**, is obtained by selecting Real and imaginary in the list of Y display modes. In this, the real and imaginary components of the voltage across the capacitor are plotted separately against frequency. The real component, shown in the upper curve, falls from 1000mV at frequencies below about 80Hz to zero at frequencies greater than about 200kHz. At f_c, it reaches its half-way value of 500mV, equivalent to –3dB, as indicated by the vertical cross-hair. The imaginary part, lower curve, has its greatest negative value of –500mV at this frequency. At this frequency the phase angle is –45°.

A third display mode is Nyquist Plot, obtained by running the same simulation, Frequency response , but with Complex plane ticked as the Y-display mode. Display, **Fig. 5**, is a plot in the complex plane, the x-axis being real and the y-axis being imaginary. Both axes are graduated in a linear voltage scale though, on the screen, the scales are not equal.

Note that in this example all the values on the *y*-axis are negative and the origin is in the top left corner. The curve passes through a set of points labelled with the frequency.

A graph of this type is most easily interpreted by reference to a set of phasors. Beginning at top right of the graph with the lowest frequency, the output is in phase with and has the same amplitude as the input, dashed line of **Fig. 6**. The real component has the value 1000mV and the imaginary component is zero.

As frequency increases up to 1592Hz, the imaginary component increases but is negative, while the real component decreases. At 1592Hz they have equal magnitude (500mV and –500mV, see Fig. 3) and the phase angle is –45°. This is the point at the bottom centre of the graph in Fig. 5, the curve being the locus of the tip of the phasor as frequency changes.

As frequency increases further, we follow the curve around to the left, both components decreasing. You will notice that the real component decreases at a faster rate and thus, at the limit, the phase angle is –90°.

Designing active filters

As a change of approach, I will use *Mathematica* to assist with the designing of a first-order low-pass active filter, based on an operational amplifier, **Fig. 7**. It is to have a dc gain of 25, and a cut-off frequency of 10kHz.

Decide on a possible value for the capacitor, say 2.2nF. Calculating the values of the resistors follows a routine. As in the programs described last month, set up a Notebook that begins with the definition of a function LowPass, **Fig. 8**. This needs 3 values: dc gain (*a*), cut-off frequency (*fc*) and capacitor value (*c*). It calculates the values of the input resistor (*r*), the amplification resistor (*ra*), and the feedback resistor (*rf*).

Equations for these calculations appear in the definition, and balance the bias current by making *ra* and *rf* in parallel equal to *r*. These calculations would normally be done by hand, on paper, but here we can run through them simply by clicking the Action menu and selecting Evaluate notebook. As explained last month, you can also click on and evaluate one stage at a time when testing and debugging the routine.

When the function is called, it returns the value of *rf*, given by the final equation in the definition. Commands '*ra*' and '*r*' following this causes the calculated values of *ra* and *r* to be displayed. These are then converted to standard resistor values (see panel). In this way, the three resistor values required for building the filter are obtained, assuming an ideal op-amp.

Figure 8 has a final line needing more explanation. The function BodePlot is one defined in a package specially intended for engineers. This is the *Electrical Engineering Pack*, obtainable as an optional extra from the publishers of *Mathematica*. It consists of a number of Notebooks, describing various ways of using *Mathematica* in electrical and electronic applications. These are presented as a printed book and as a series of files on disk ready to load when running Mathematica.

More interestingly for us, it also contains a package of functions relevant to electrical and electronic engineering. The Bode Plot is one of the routines included in the *EE* package and

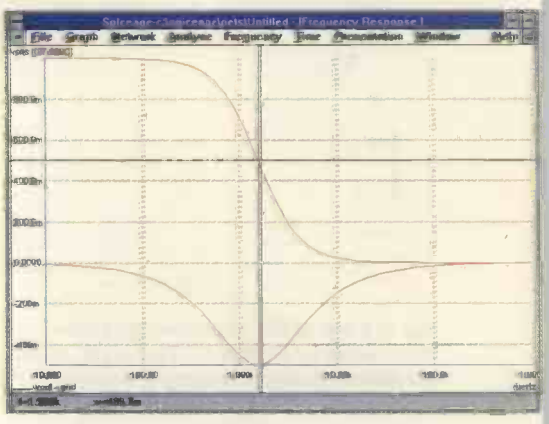


Fig. 4. In this curve, frequency response of the low-pass filter is plotted in terms of the real and imaginary parts of the output voltage phasor.

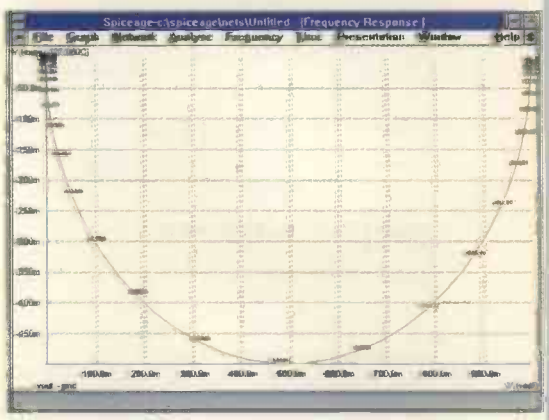


Fig. 5. A Nyquist Plot in the complex plane defines the locus of the apex of the output voltage phasor as frequency rises from 0Hz (top right) to 1MHz (top left).

Packages

A number of standard packages are included with *Mathematica*. These provide some of the routines which are less often required than those in the kernel. Examples are statistical functions, and calculus functions such as the Laplace transform. These are read into the program by a command such as

```
<< Calculus`LaplaceTransform`
```

or

```
Needs["Calculus`LaplaceTransform`"]
```

It can be arranged that a package is loaded automatically when one of its functions is called. With the engineering package, the easiest method is to begin the session by typing:

```
Needs["EE`Master`"]
```

This loads all the functions that are present in the EE package.

Standard resistor values

The calculations return the values of resistors to several significant figures, usually at least five. In practice, a circuit is built from resistors of the E12 or E24 series and only rarely from E48 or higher-precision resistors. The EE package has a routine *SelectResistor* to pick out the standard resistor nearest to any given resistor value. The syntax is:

```
SelectResistor[resistance, tolerance]
```

In Fig. 8 this routine is used for finding practical values for *R*, *RA* and *RF*, assuming 5% tolerance. In this Notebook, the selected value is assigned to the variable before calling BodePlot. Because of this, the plot shows the behaviour of the filter using standard resistors.

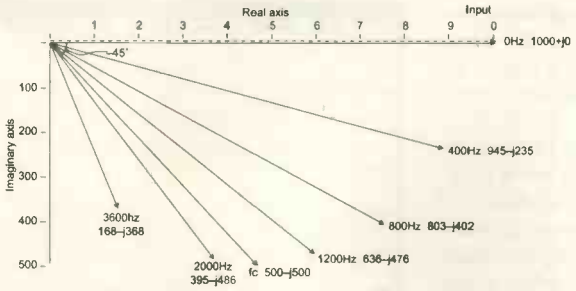


Fig. 6. A few of the output voltage phasors represented by the Nyquist Plot of Fig. 45 show how the almost semicircular curve is traced.

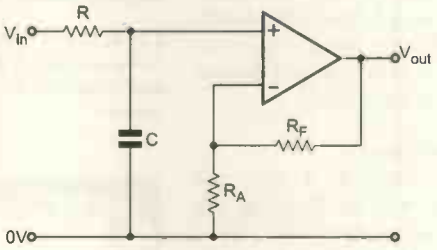


Fig. 7. A low-pass active filter based on op-amps, to be used as a basis for analysis by Mathematica.

```
CBD04 - Low-pass RC filter

LowPass[a_,fc_,c_]:= (r=1/(6.28319 fc c);rf=r (a-
Input["DC gain"];
a = %;
Input["Cut-off frequency"];
fc = %;
Input["Capacitor"];
c = %;
LowPass[a, fc, c]
r
SelectResistor[rf,0.05];
rf = %
SelectResistor[r,0.05];
r = %
BodePlot[(a/(2 Pi r c))/(I w+1/(2 Pi r c)),
{w,100,10^7}]
```

Fig. 8. Mathematica procedure for obtaining a Bode Plot for a low-pass active filter such as that in Fig. 7.

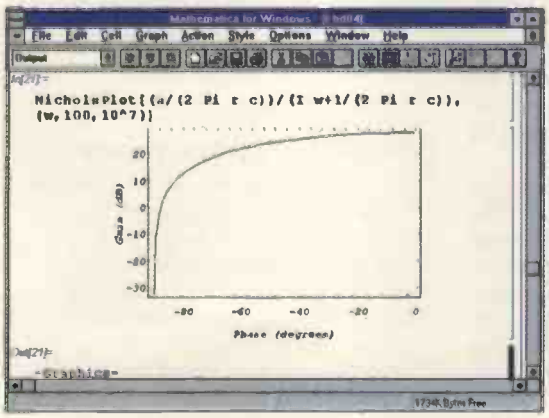


Fig. 9. This procedure modification gives a Nichols Plot. Gain is related to phase angle. Curve shows gain reducing and phase lag increasing at higher frequencies.

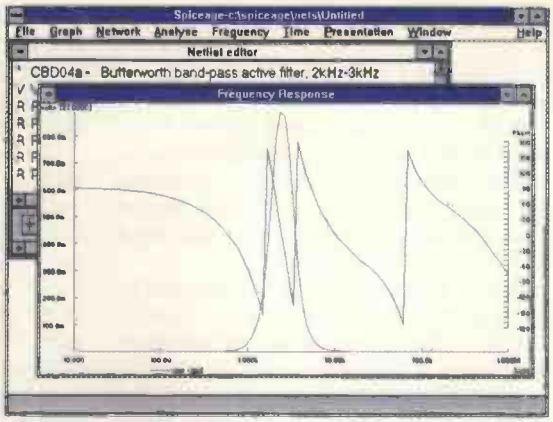


Fig. 11. Transient analysis shows peak response at 2.5kHz, and a fall-off on either side of this at the specified rate.

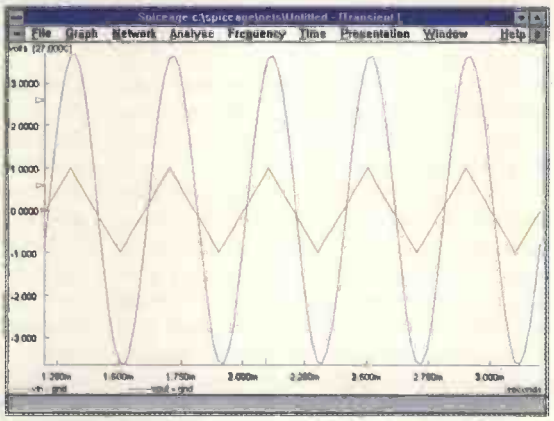


Fig. 12. Band-pass filter of Fig. 10 in action. A 2.5kHz triangle wave is filtered to a 2.5kHz sine wave, all harmonics are filtered out because they are well above the pass band.

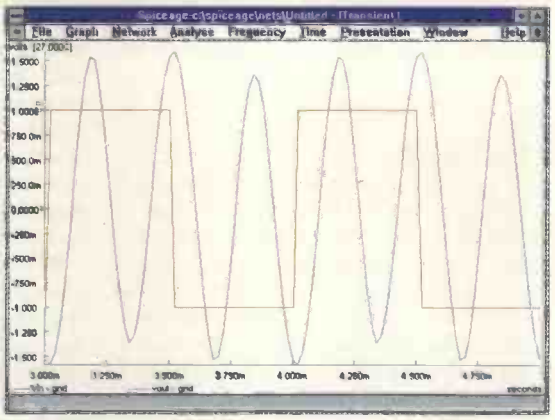


Fig. 13. When filter input is a 1kHz square wave, well below the pass band, only the 3kHz sine wave component comes through strongly. This transient analysis plots the filter's 1kHz square input and 3kHz sine output.

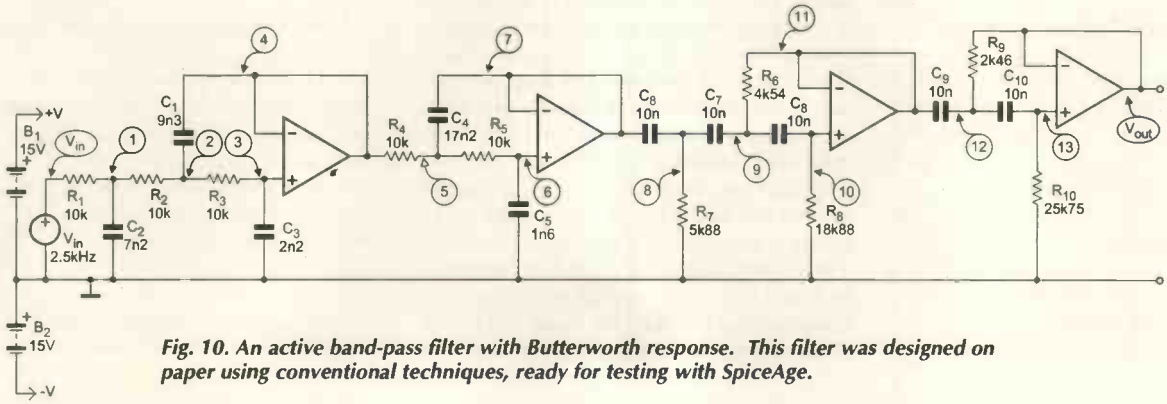


Fig. 10. An active band-pass filter with Butterworth response. This filter was designed on paper using conventional techniques, ready for testing with SpiceAge.

Enlarging the plot

Although the graphs are too small to read when first plotted, they are easily enlarged. Place the cursor anywhere in the cell – except for the cell bracket – and click the mouse. This makes a box appear around the graphs. The box has handles comprising small shaded squares; clicking on one of these and dragging it toward the edge of the screen causes the display to be enlarged. Click in an adjacent cell to remove the box.

I will discuss several others in due course.

Syntax of BodePlot is:

BodePlot[transfer-function, {frequency, minimum, maximum}]

In the case of the first-order filter, the transfer function in the frequency domain is:

$$H(s) = \frac{A/2\pi RC}{s + 1/2\pi RC}$$

This is incorporated into the function in Fig. 8, substituting jω for s, but using *I* for j). In curly brackets we have ω, the frequency variable, with 100 and 10^7 setting the plot to range from 100Hz to 10MHz.

Evaluating the Notebook, input '25' as the dc gain, '10000' as the cut-off frequency and '2.2 10^–9' (note the space between the '2.2' and the '10') as the capacitor value. The program responds by displaying 180858 as the value of *rf*, and 7234.31 for *R*. These are converted to 180kΩ and 7.5kΩ respectively. Then it displays the Bode plot in the form of two graphs.

The upper graph shows amplitude against frequency. It is plotted on a decibel scale, with 28dB (=20log25) as the reference; the amplitude falls by 3dB, to 25dB, at the cut-off frequency, as indicated by the cross-hairs. The lower graph is phase against frequency, falling from 0° to –90° over the displayed range. Cross hairs indicate that the output lags the input by 45° at the cut-off frequency.

Other plots

The *Engineering Pack* of *Mathematica* has functions for two more useful plots, one of which is the Nyquist plot. The syntax is the same as for the Bode plot; just substitute 'NyquistPlot' for 'BodePlot' in Fig. 8 and evaluate the Notebook.

The other function is the Nichols Plot, in which the gain of the filter in decibels is plotted against the phase angle. Substitute 'NicholsPlot' for 'BodePlot' in Fig. 8 and evaluate the Notebook. In **Fig. 9**, gain rises from a low level when the phase angle is –90° at high frequency to 28dB when the phase angle is close to 0°, i.e. at low frequency.

Filter design

The task is to design an active band-pass filter with the Butterworth response, using *741* op-amps. The –3dB frequencies are 2kHz and 3kHz; response is 30dB down at 1kHz and 6kHz. The filter consists of a low-pass filter cascaded with a high-pass filter.

The standard routine for deciding how many poles are required and for calculating resistor and capacitor values involves very little calculation. Most of the values are obtained by consulting tables. It is hardly necessary to invoke the aid of *Mathematica*.

You will find that both the low-pass and high-pass sections must be five-pole filters. Each consists of a three-pole filter followed by a two-pole configuration. **Figure 10** shows the circuit and is marked with the calculated values. Having completed the design, we use *SpiceAge* to verify it and to investigate some of its properties.

Power supply to the capacitor is provided in the netlist by two 15V batteries connected in series, and to the positive, negative and ground lines. Input is a sine wave voltage generator, amplitude 1V, first set to 2.5kHz, which is the mid-frequency of the filter.

The procedure is the same as if the filter has

Creating .WAV files

Readers whose simulation software does not have the facility to generate .WAV files may make use of this simple technique. You need a program for generating a .WAV file from an equation. A suitable program, which is a complete sound file editor, is *GoldWave*, by Chris Crain. This is available as shareware from Chris at PO Box 51, St. John's, NF, Canada A1C 5H5.

Internet: chris3@garfield.cs.mun.ca. Registration fee is $30 Canadian. It is also on the diskette packaged with *Soundblaster: The Official Book* by Peter M. Ridge, David M. Golden, Ivan Luk and Scott E. Sindorf, 2nd Edition, published by Osborne/McGraw-Hill.

When you have performed a transient analysis, preferably of five or more cycles, obtain a Fourier transform. Use the cross-hairs to measure the amplitude of the fundamental and each harmonic. Also measure their phase angles. Given this information, write an equation to reconstruct the waveform.

As an example, here are the data for a 1kHz triangular wave with a 1V amplitude:

Frequency	Amplitude (V)	Phase
1kHz	0.8063	–90°
3kHz	0.09019	+90°
5kHz	0.03247	–90°
7kHz	0.01647	+90°
9kHz	0.01013	–90°

Written as a Fourier series:

$$y=-0.8063\sin x+0.09019\sin 3x-0.03247\sin 5x+0.01647\sin 7x-0.01013\sin 9x$$

The angle should include the phase angles but, since all angles are either +90° or –90°, it is simpler to alter the angle of reference and give the terms the sign of the phase angle.

The right-hand side of this equation is typed into the *GoldWave* Expression Evaluator, substituting 't*1000' for *x* to obtain a 1kHz wave. The expression was evaluated for t=0 to t=2 to give a two-second file. You could substitute any other factor instead of 1000 to obtain sounds of other frequencies.

The same triangle wave is filtered through a three-pole *RC* low-pass filter with a –3dB point of 2kHz. The output transient is evaluated from 2ms to 12ms to eliminate the starting-up transient. After a transient analysis as above, the Fourier analysis gives:

Frequency	Amplitude (V)	Phase
1kHz	0.2773	178°
3kHz	0.00758	–60°
5kHz	0.00103	+90°
7kHz	0.00025	–108°

Here it is necessary to take full account of the phase angle, after converting it into radian (all terms positive):

$$y=0.2773\sin(x+3.11)+0.00758\sin(3x-1.05)+0.00103\sin(5x+1.57)+0.00025\sin(7x-1.88)$$

Type this in, substituting 't*1000' for *x*, as before. The whole expression is bracketed and multiplied by three to compensate for the attenuation of the filter. The result is a .WAV file sounding like a 1kHz sine wave, which is virtually what it is after such heavy filtering.

been assembled with real components. I will demonstrate how it works. The advantage with using a simulator is that it is not possible to burn out expensive components because of wrong connections. Additionally, there is no problem with electrostatic charges when using cmos components.

A probe is set to monitor *vout*. Call up the Time selector box and enter a start time of 0s, a stop time of 400µs and a step time of 8µs. This gives time for one complete cycle

The first test, a Transient analysis, gives an output of 400V amplitude; obviously something is wrong. Instead of desoldering connecting wires, it is possible to 'isolate' parts of the circuit and test them individually for faults; simply type an asterisk at the beginning of any statement to remove the component from the circuit.

Check that the remaining components have the correct temporary connections and test again. Isolating the first op-amp still produces an excessively high output, so obviously something more fundamental is wrong. Careful scrutiny of the netlist reveals a typing error; there is 'v–' where there should be '–v'. Once this is corrected the circuit works perfectly. The output amplitude is about $^1/_5$ that of the input and appears to be almost in phase.

To confirm that the filter behaves as intended, set the Frequency range to extend from 10Hz to 1MHz and run a Frequency response analysis. The result, **Fig. 11**, shows that the response is almost exactly as required. At the low end it is –30dB at 1kHz, and –3dB at 1kHz. At the high end it is –3dB at 3.2kHz and –30dB at 6.1kHz.

The pass-band is narrow and fall-off is steep on both sides so that the typical flat pass-band of a Butterworth filter is not shown. Also shown in the graph is how phase angle varies with frequency. The angle decreases from 90° at low frequencies to –180° at about 2kHz. It continues to fall, but having completed half a circle, now appears as +180° on the graph falling to 0° (really –360°) at 2.5kHz. In continues to fall as frequency increases.

Filtered waveforms

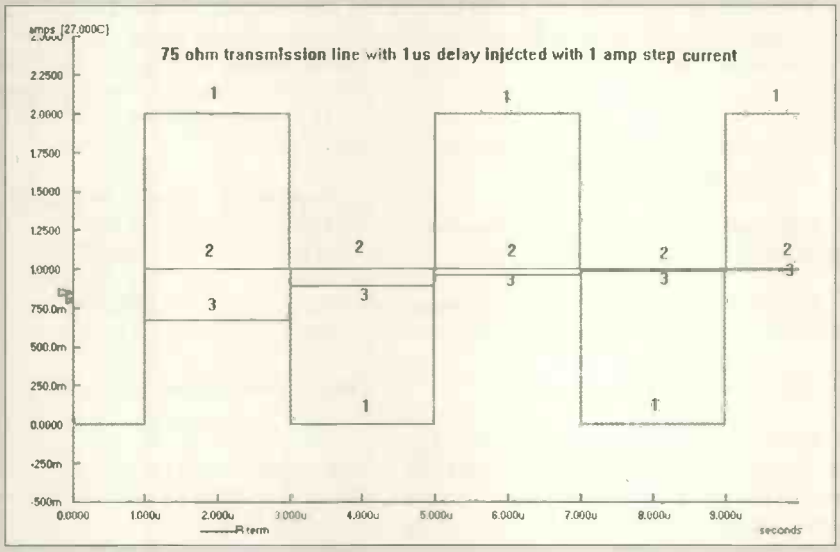
SpiceAge can show the effect of the filter on various waveforms. Change the excitation of the voltage generator to 'triangular' and set the Time selector to start at 0s, stop at 2ms with steps of 20µs. This gives time for 5 complete cycles.

Transient analysis shows that the output amplitude increases gradually during the first three cycles and is constant thereafter. This is because it takes about that length of time for the capacitors to become charged to their operating levels. Such a result is not a good basis for a Fourier analysis.

Re-set the timing to begin at 1.2ms and stop at 3.2ms. The first three cycles are ignored and the fourth to eighth cycles displayed, **Fig. 12**. In the figure, the output appears to have a greater amplitude than the input, but this is because a scale factor of times five is set for the output waveform.

Input waveform is clearly triangular but the

Win Spiceage for Windows



Two readers answering the questions below correctly will win a copy of *SpiceAge for Windows* Level 3 – base professional level – worth £395+VAT. Simply answer the following questions and complete the tie break, posting your reply to arrive at the offices of Those Engineers before 25 February 1995.

Q1. *SpiceAge for Windows* is written in which country: USA, Germany, UK, Israel, Australia, Japan?

Q2. In a lossless circuit, resonance is given by $\omega=1/(LC)^{0.5}$rad/s. Write down the analogous expression for a mechanical spring plus mass system. Please define completely the terms within your expression.

Q3. Which of the following traces which show the current in the terminating resistor is the correct response of a 75Ω transmission line terminated with a 150Ω resistor to which a current of 1A is suddenly applied?

Q4. You are on site repairing a board for which you need a 20kΩ 5% resistor. You have just dropped your ohm meter in a puddle and your tool kit contains only one each of 5% values fitting the 10, 12, 15, 18, 22, 33 and 47 decade multipliers between 1kΩ and 47kΩ. What do you do to keep within the original value to 3 significant figures?

Q5. Tie breaker. Complete the following in no more than 100 words. "I would be interested in using *SpiceAge* to..." Your reply will be judged (i) on its feasibility and (ii) on how interesting your application is.

Your answers must arrive before 25th February 1995. The winners will be announced in the April 1995 edition of *Electronics World + Wireless World*. No purchase is necessary. The judges' decision is final. The competition is open to EC residents only but is not open to employees or suppliers of Those Engineers Ltd. No correspondence will be entered into. Send your answers by post please to: Those Engineers, Sawcomp, 31 Birkbeck Road, London NW7 4BP.

output appears to be a sine wave, almost in phase with the input – actually about 360° out of phase, as explained above. Fourier analysis shows a single spectrum line at the fundamental frequency, 2.5kHz. Harmonics are well above the pass-band so are considerably attenuated. The output is an almost pure sine wave.

Try the effect of the filter on a square wave, by changing the excitation of the generator. Also reduce its frequency to 1kHz, to bring it below the pass-band. Display the transient analysis from the second to the fourth cycles. As before, the output appears to be a pure sine wave, but its frequency is 3kHz, not 1kHz, **Fig. 13**. A square wave has only the even harmonics and an examination of the subsequent Fourier analysis has only three significant spectrum lines:

- 1 kHz, amplitude 40mV – the fundamental, but much reduced by filtering
- 3 kHz, amplitude 289mV – second harmonic, within the pass-band
- 5 kHz, amplitude 15mV – fourth harmonic, reduced by filtering

Making sounds

Although a simulator can tell you all you need to know about the voltages and currents in a circuit – and display graphs showing the shapes of the waveforms – there are occasions on which it would be informative to hear a waveform. This is important to anyone designing audio equipment, in which subjective judgements play no small part.

There are several ways in which you can make your circuits 'emit' sounds. *SpiceAge* is able to produce a file called a log file which is an ascii file containing a table of the output voltage at regular intervals of time. This is the data which is used by *SpiceAge* to plot graphs, such as Fig. 12.

Log files are of no direct use for producing sound, but their data is convertible into the format of a .WAV file. A .WAV file is one of the standard file formats used by computer sound cards. When the card reads the file, it produces the corresponding sound.

Most recent versions of *SpiceAge* have a routine for converting a log file to a .WAV file, which is playable on a sound card such as those in the *Soundblaster* range. The file is monophonic, so the inexpensive *Soundblaster* V2 is adequate. The files play on stereo sound cards too, including 16-bit cards.

When creating a .WAV file in *SpiceAge*, the first stage is to set up the netlist. Next select Log file in the Presentation menu. In the Time selector box enter a suitable start and stop time. Only one cycle is required but, with reactive circuits, allow a few cycles to run before the analysis period to allow values to settle.

Step time must not be less than 16µs. In the most recent version, the time selector accepts 'samples per second' as an alternative to sample times. Set Probe 1, to measure input or output voltage. Run a Transient analysis and note the hard disk activity as the circuit is analysed and the data is stored in the log file. The graph is displayed as usual after the analysis is complete.

In the File menu select Convert log file to .WAV format. A dialogue box asks you to name the log file to be converted (for example, the one just created), then a box asks you to provide a name for the .WAV file.

Assuming that you have a *Soundblaster* or similar sound card installed, play the file by selecting Play sound. A dialogue box lists the .WAV files available on the current drive; select one of these and the sound begins immediately. Another box appears inviting you to 'Stop sound' by clicking on a button.

The files produced by *SpiceAge,* derived from the transient analysis, last only for the period analysed. This period is unlikely to be more than a few milliseconds Correspondingly, the files require few bytes. The play routine of this program repeats the file until told to stop – unlike most file-playing programs which play a .WAV file only once. ■

TELNET

8 CAVANS WAY, BINLEY INDUSTRIAL ESTATE, COVENTRY CV3 2SF
Tel: 01203 650702
Fax: 01203 650773
Mobile: 0860 400683

(Premises situated close to Eastern-by-pass in Coventry with easy access to M1, M6, M40, M42, M45 and M69)

OSCILLOSCOPES

Gould OS4000, OS4200, OS4020, OS245 ... from £125
Gould OS3000 – 40MHz, dual ch. ... £250
Gould 4035 – 20MHz digital storage ... £600
Gould 4050 – 35MHz digital storage ... £750
Gould 5110 – 100MHz intelligent oscilloscope ... £950
Hewlett Packard 1707A, 1707B – 75MHz dual ch. ... from £275
Hewlett Packard 1740A, 1741A, 1744A, 100MHz dual ch. from £350
Hewlett Packard 54201A – 300MHz digitizing ... £1950
Hewlett Packard 54504 – 400MHz digitizing (As new) ... £3950
Hitachi V-212 – 20MHz dual trace ... £175
Hitachi V-422 – 40MHz dual ch. ... £300
Nicolet 3091 – Low freq D.S.O. ... £1100
Philips 3315 – 60MHz D.S.O. ... £750
Tektronix 468 – 100MHz D.S.O. ... £800
Tektronix 2213 – 60MHz dual ch. ... £425
Tektronix 2215 – 60MHz dual ch. ... £450
Tektronix 2235 – 100MHz dual ch. (portable) ... £800
Tektronix 2246 – 100MHz 4 channel (as new) ... £995
Tektronix 2246 – 100MHz 4 channel with opt 9 ... £1500
Tektronix 2335 – 100MHz dual ch. (portable) ... £750
Tektronix 2445 – 150MHz 4 channel ... £1300
Tektronix 464/466 – 100MHz, storage ... from £350
Tektronix 465/465B – 100MHz dual ch. ... from £350
Tektronix 7313, 7603, 7613, 7623, 7633, 100MHz 4 ch. ... from £300
Tektronix 7704 – 250MHz 4 ch. ... from £650
Tektronix 7834 with 7B42, 7B80, 7B85 – Plug-ins (Storage 400MHz) ... £1500
Tektronix 7904 – 500MHz ... from £850
Telequipment D68 – 50MHz dual ch. ... £200
Philips 3206, 3211, 3212, 3217, 3226, 3240, 3243, 3244, 3261, 3262 (2ch + 4 ch.) ... from £125 to £350
Philips PM3208 – 20MHz dual channel ... £200
Philips PM3295A – 400MHz dual channel ... £1950
Philips PM3296 – 350MHz dual channel ... £1800

Other scopes available too

SPECTRUM ANALYSERS

Hewlett Packard 3580A – 5Hz – 50KHz ... £995
Hewlett Packard 3582A – 25KHz analyser, dual channel ... £2500
Hewlett Packard 3585A – 20Hz – 40MHz ... £3750
Hewlett Packard 8590A – 10MHz – 1.5GHz (as new) ... £4300
Hewlett Packard 8754A – Network Analyser 4 – 1300MHz ... £3500
Hewlett Packard 182T with 8559A (10MHz – 21GHz) ... £3750
Hewlett Packard 8561A – 1KHz-6.5GHz High performance ... £12,000
Hewlett Packard 3561A – Dynamic signal analyser ... £3750
Hewlett Packard 8594E – (NEW) – 9KHz-2.9 GHz ... £10,000
Marconi 2370 – 110MHz ... £995
Marconi 2371 – 30Hz–200MHz ... £1250
Rohde & Schwarz – SWOB 5 Polyskop 0.1 – 1300MHz ... £2750
Schlumberger 1250 – Frequency response analyser ... £2500
Texscan AL51A – 1GHz ... £995
Tektronix 7L14 with 7603 – Mainframe (1.8GHz) ... £2000

MISCELLANEOUS

Anritsu MG642A Pulse pattern generator ... £1500
Ballantine 323 True RMS voltmeter ... £350
Datalab DL 1080 – Programmable Transient Recorder ... £350
E.I.P. 331 18GHz frequency counter ... £850
Farnell RB 1030-35 Electronic load 1Kw ... £450
Farnell 2081 R/F Power meter ... £350
Farnell TSV70 MkII – Power Supply (70V–5A or 35V–10A) ... £225
Ferrograph RTS2 Audio test set with ATU1 ... £500
Fluke 5101A – Calibrator AC/DC ... £3500
Fluke 5101B – Calibrator AC/DC ... £6500
Fluke 5220A – Transconductance Amplifier (20A) ... £3000
General Rad 1658 LCR Digibridge ... £250
Helden 1107 – 30v-10A Programmable power supply (IEEE) ... £650
Hewlett Packard 436A Power meter + 8481A sensor ... £950
Hewlett Packard 1630G – Logic Analyser (65 channel) ... £850
Hewlett Packard 3437A System voltmeter ... £350
Hewlett Packard 3438A Digital multimeter ... £200
Hewlett Packard 3490A Digital multimeter ... £250
Hewlett Packard 3586A – Selective level meter ... £1750
Hewlett Packard 3702B/3705A/3710A/3716A Microwave link analyser ... £1500
Hewlett Packard 3711A/3712A/3791B/3793B Microwave link analyser ... £3500
Hewlett Packard 3760/3761 Data gen + error detector ... each £300
Hewlett Packard 3762/3763 Data gen + error detector ... each £350
Hewlett Packard 3764A Opt.002 – Digital Trans. Analyser ... £3500
Hewlett Packard 3777A Channel selector ... £250
Hewlett Packard 3779A/3779C Primary multi. analyser ... £600/£1000
Hewlett Packard 4193A Vector impedance meter ... £3250
Hewlett Packard 4261A – LCR Meter ... £400
Hewlett Packard 4271B – LCR Meter ... £900
Hewlett Packard 5150A Thermal printer ... £275
Hewlett Packard 5316A – Universal counter HPIB ... £550
Hewlett Packard 5316B – Universal counter HPIB ... £750
Hewlett Packard 5385A – Frequency counter 1GHz (HPIB) with Opts 001/003/004/005 ... £995
Hewlett Packard 59501B HP IB isolated D/A power supply programmer ... £150
Hewlett Packard 6181C D.C. current source ... £150
Hewlett Packard 6261B Power supply 20V–50A ... £600
Hewlett Packard 6453A – Power supply 15V–200A ... £1250
Hewlett Packard 7402 Recorder with 17401A x 2 plug-ins ... £300
Hewlett Packard 8005B Pulse generator ... £250
Hewlett Packard 8011A Pulse gen. 0.1Hz – 20MHz ... £500
Hewlett Packard 8406A Frequency comb. generator ... £400
Hewlett Packard 8443A Tracking gen/counter with 1EEE ... £300/£400
Hewlett Packard 8620C Sweep oscillator mainframe ... £400
Hewlett Packard 8750A Storage normaliser ... £375
Hewlett Packard 8657B – Synthesised Sig. Gen. (2060MHz) ... £8250
Hewlett Packard 8901B – Modulation Analyser AM/FM 150KHz – 1300MHz ... £3750
Hewlett Packard 3456A Digital voltmeter ... £750
Hewlett Packard 3488 – HP-IB switch and control unit ... £500
Hewlett Packard 6623A – Triple output system power supply ... £1950
Hewlett Packard 6624A – Quad output system power supply ... £2250
Hewlett Packard 8656A – 990MHz synth signal generator ... £1500
Hewlett Packard 8903B – Audio Analyser (20Hz – 100KHz) ... £2750
Hewlett Packard 8920A – R/F communications test set (as new) ... £7000
Hewlett Packard 35677A – S Parameter Test Set ... £1250
International Light – IL 1700 research radiometer with Erythemal sensor head ... £1250
Leader LCR745G – LCR Meter ... £1150
Lyons PG73N/PG75/PG2B/PG Pulse generator ... from £225
Marconi 2306 Programmable interface ... £500
Marconi 2337A Automatic dist. meter ... £150
Marconi 2356 20MHz level oscillator ... £300
Marconi 2432A 500MHz digital freq. meter ... £200
Marconi 2830 Multiplex tester ... £1000
Marconi 2831 Channel access switch ... £400
Marconi 893B A/F power meter ... £325
Multicore "Vapourette" bench top vapour phase SMD soldering machine (new and unused) (£1100+ new) ... £650
Philips PM 5167 10MHz function gen. ... £400
Philips PM 5190 LF synthesizer w/th GPIB ... £800
Philips 5390 1GHz signal gen. ... £1250
Philips PM 5716 Pulse generator high freq. mos ... £600
Philips PM 6672 1GHz timer counter WF 1EEE ... £650
Philips PM 8272 XYT chart recorder ... £500
Racal 9301A True RMS R/F millivoltmeter ... £300
Racal Dana 1992 – 1300MHz frequency counter opts 4B+55 ... £800
Racal Dana 3100 40–130MHz synthesiser ... £750
Racal Dana 5002 Wideband level meter ... £650
Racal Dana 5003 Digital m/meter ... £150
Racal Dana 9000 Microprocessing timer/count, 52MHz ... £250
Racal Dana 9009A Modulation meter (new version) ... £300
Racal Dana 9081 Synth. sig. gen. 520MHz ... £550
Racal Dana 9084 Synth. sig. gen. 104MHz ... £450
Racal Dana 9242D Programmable PSU 25V–2A ... £300
Racal Dana 9246S Programmable PSU 25V–10A ... £400
Racal Dana 9301A/9302 R/F Millivolt meter ... from £300
Racal Dana 9303 True RMS/RF level meter ... £650
Racal Dana 9341 LCR databridge ... £250
Racal Dana 9500 Universal timer/counter 100MHz ... £200
Racal Dana 9921 3GHz frequency counter ... £450
Rohde & Schwarz BN36711 Digital Q meter ... £400
Rohde & Schwarz LFM2 Sweep generator 0.02 – 60MHz ... £1500
Rohde & Schwarz SCUD Radio code test set ... £1500
Rohde & Schwarz SMFP2 Mobile tester ... £4000
Schlumberger SI 4040 – Stabilock, high accuracy 1GHz radio test set ... £8500
Schlumberger 4923 – Radio Code Test Set ... £2000
Schlumberger 2720 – 1250MHz Freq. Counter ... £600
Systems Video 1258 Waveform analyser + 1255 vector monitor + 1407 differential phase & gain module + 1270 remote control panel ... £2250
Thurlby Thandar TG1304 Programmable Function Generator (13MHz) ... £600
Time 9811 Programmable resistance ... £600
Time 9814 Voltage calibrator ... £750
W&G MU3 Test point scanner ... £500
W&G PCM3 Auto measuring set for telephone channels ... £950
Watanabe WTR211 3 pen plotter ... £250
Weller D800/D801 Desoldering station ... £175
Weller D900 Desoldering station ... £150
Wiltron 352 Low freq. differential input phase meter ... £350
Wiltron 560 Scalar Network analyser ... £800

MANY MORE ITEMS AVAILABLE – SEND LARGE S.A.E. FOR LIST OF EQUIPMENT ALL EQUIPMENT IS USED – WITH 30 DAYS GUARANTEE. PLEASE CHECK FOR AVAILABILITY BEFORE ORDERING – CARRIAGE & VAT TO BE ADDED TO ALL GOODS

CIRCLE NO. 120 ON REPLY CARD

A question of balance

Two transmitters into one aerial system, two signal generators connected to a circuit under test, one generator feeding multiple outputs... All these applications require load balancing for correct operation. Steve Winder offers a thumbnail tutorial on obtaining the perfect balance.

Power combiners and splitters find use in rf whenever there is a need to bring sources or loads out to a single port. Combiners are physically the same as splitters: one device can serve two functions. Inputs become outputs and outputs become inputs.

Simply joining sources together will not do; impedances must be matched and isolation between the two sources may be required. A typical use would be in intermodulation distortion testing where two signal generators are coupled to a single output connected to the unit under test. Another relates to single sideband circuits, where two phase shifted signals are combined to eliminate one of the sidebands.

Power splitters are used whenever one signal source is used to drive two or more circuits. For example, this could be when two radio receivers use the same antenna.

The design coupler naturally depends on the application. Combiners used for two-tone testing require isolation between the two input

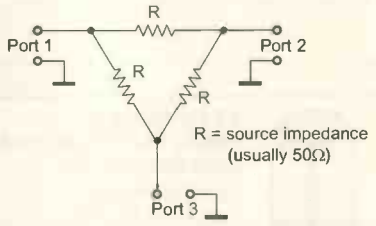


Fig. 1a. Delta resistive splitter network. Each resistor should equal the source resistance for perfect matching.

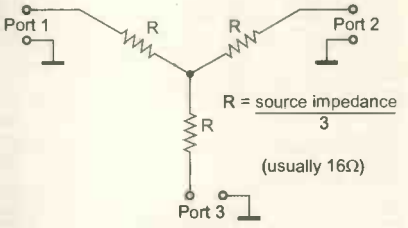


Fig. 1b. Star resistive divider. This is functionally the same as the circuit shown in Fig. 1a.

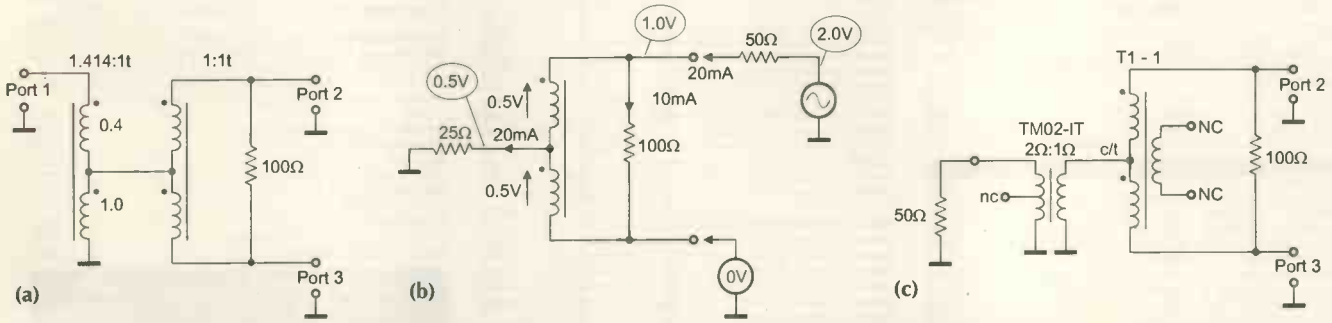


Fig. 2. Derivation of the transformer coupled power divider. a) shows the basic circuit. The first transformer changes the source impedance from 50Ω to 25Ω while the second provides the balancing and isolation action. When ports 2 and 3 see an equal load, there will be no power dissipated in the 100Ω resistor. Fig. 2b) is the circuit model while c) is a practical implementation with readily available prewound components.

ports and transformer coupled circuits give this isolation.

Where the two signals widely differ in frequency, a diplexer could be the best choice, for instance to separate a vhf radio signal and a uhf television signal transmitted over the same co-axial cable. The following descriptions of power splitters and combiners assume a 50Ω source and load impedance is assumed.

Resistive power splitters

Resistive power dividers can be realised in either of the two forms, shown in **Fig. 1**. Form *a* uses a delta network of resistors, each equal in value to the source impedance, 50Ω (51Ω will do). Form *b* is a star network of resistors, each resistor has a value equal to one third of the source impedance. In a 50Ω system, the three resistors in the star network will have a perfect value of 16.67Ω. In both cases, input impedance matching is dependent on the impedance of both loads.

When a signal is applied to any port of the delta network, the other two ports will deliver a level equal to half the applied voltage. This is one quarter of the input power. Since both outputs have the same voltage on them, no current flows through the resistor connected between the output ports. Each of the other resistors in the delta network is in series with a load resistor of equal value. Half the applied voltage will be dropped across resistors in the splitter, leaving half of the voltage across the load.

Looking at the input and output ports, the star network behaves in an identical way to the delta network. The voltage at the two output ports is half the applied voltage. Both star and delta networks deliver just 3dB of isolation between ports.

Transformer coupled dividers

Using transformers in a power splitter, or combiner, enables isolation of the two output ports. This is important in some applications, such as at the output of a diode mixer where signals could mix to generate unwanted products. Isolation between the two outputs is often about 35dB. It also eliminates the losses inherent to the resistive splitter. Half the power goes to each output resulting in a 3dB reduction in signal level. Some transformer losses are inevitable however.

The transformer coupled splitter comprises two transformers, as shown in **Fig. 2a**. One is an autotransformer, the other transformer has a single centre tapped winding. The autotransformer reduces the input impedance by half, to present a 25Ω source impedance to the centre tap of the second transformer. Splitters of this type are available commercially, in modular form, from manufacturers such as Mini-Circuits[1].

When transmitting signals from port 1 to the output ports 2 and 3, an equal amount of current flows through each of the second transformer's windings. Since the currents flow in opposite directions through the two transformer windings, there is no magnetic flux produced. Without flux there is no voltage

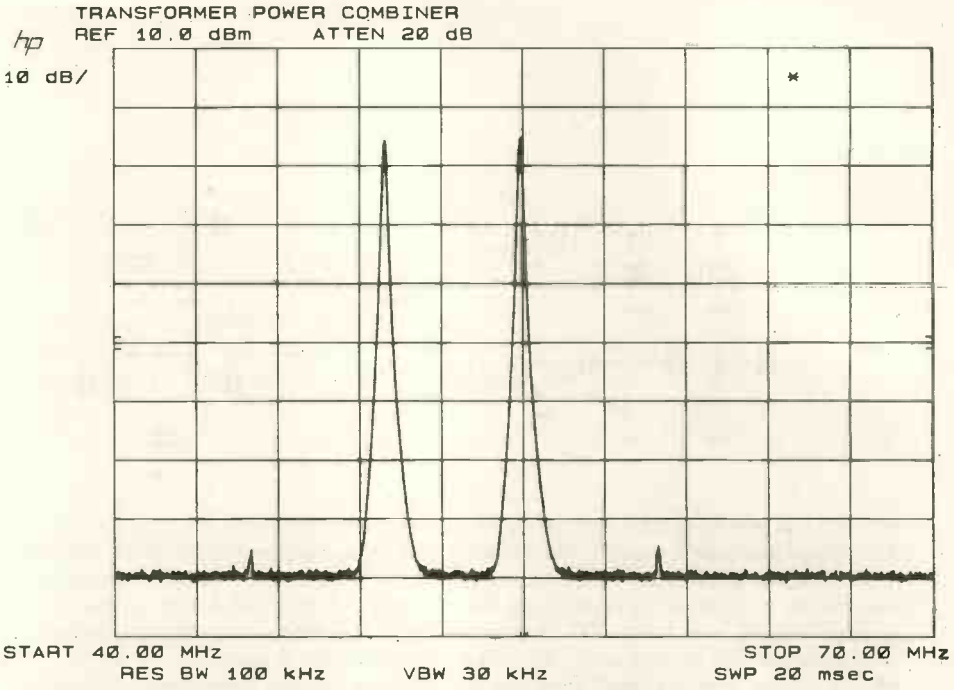


Fig. 3. The spectral plot delivered by the practical implementation of Fig. 2 demonstrates the splitting action, giving equal outputs at ports 2 and 3.

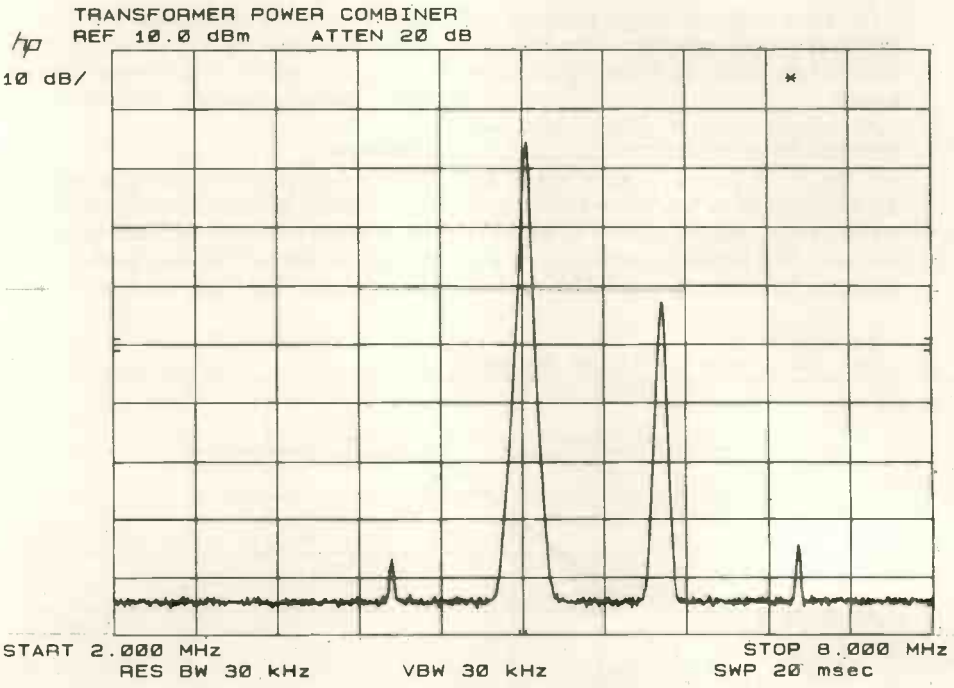


Fig. 4. Demonstrating the isolating action. Port 3 is connected to the spectrum analyser while port 1 has 5MHz signal applied (centre) and, at the same time, port 2 has a 6MHz tone applied. Both signal generator output levels are equal. The isolation achieved is about 30dB.

induced into the windings; the voltage at the auto-transformer tapping point appears equally at the two outputs. Imbalance in the output ports causes a current to flow in the 100Ω resistor connected between them: this limits the swr mismatch to 2:1 in worst case open circuit or short circuit on one port.

A model of the splitter omitting the autotransformer – the source resistance given as 25Ω for clarity – is shown in **Fig. 2b**. This illustrates what happens when a signal is applied to port 2. The ports all have 50Ω impedance, so the current flowing into port 2 with a one volt signal applied is 20mA. Since no signal should appear at port 3, it has a potential of zero volts, and it can be considered open circuit.

All the current must flow into the 25Ω resistor, producing 0.5V across it. Clearly the other 0.5V must be induced across one of the transformer windings (the upper winding in the diagram). By transformer action, the other

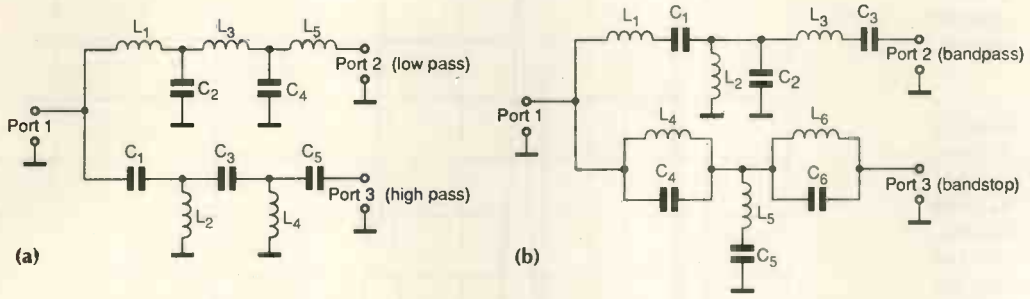


Fig. 5. Configuration (a) is a highpass/lowpass diplexer arrangement suitable for frequency splitting, for instance to a common aerial system. Diagram (b) demonstrates a bandpass/bandstop arrangement which could deliver a predictable termination to an impedance sensitive diode mixer.

winding will also have 0.5V induced into it. The voltage produced is negative with respect to the centre tap point. However, the centre tap potential is at 0.5V so, by subtracting the winding voltage, port 3 is at 0V. This also means that one volt appears across the 100Ω internal resistor, drawing 10mA from port 2. This accounts for the 3dB power loss when transmitting signals into ports 2 (or 3) and out of port 1.

The autotransformer simply translates the 50Ω system input impedance to the 25Ω presented at the centre tap of the second transformer.

An equivalent power splitter circuit was built from standard Mini-Circuits transformers. The circuit diagram is given in **Fig. 2c**. An autotransformer was not available, so a 1.414:1 turns ratio transformer (*TMO2-1T*) was used. The second transformer used just one centre tapped winding of a *T1-1*, the secondary winding being left open circuit.

With no adjustments, this simple equivalent circuit produced a useable performance, as shown in **Figs 3** and **4**. The spectral plot in Fig. 3 demonstrates the splitting action, giving equal outputs at ports 2 and 3. In Fig. 4 the isolating action is shown; port 3 is connected to the spectrum analyser while port 1 has 5MHz signal applied (centre) and, at the same time, port 2 a 6MHz tone applied. Both signal generator output levels are equal. The isolation achieved is about 30dB. Carefully designed splitters often achieve 40dB or more isolation. This is generally frequency dependent.

Diplexers

Diplexers are power combining and splitting circuits which have the advantage of producing no power loss. They use filters to separate or combine different frequency bands, and this limits their use. The filters may be either highpass and lowpass, or bandpass and bandstop. These two circuit configurations are illustrated in **Fig. 5**.

It is important that the –3dB frequency points are the same for both filters; a diplexer using a bandpass filter with a 1MHz to 1.5MHz passband must be combined with a bandstop filter that has a passband of 1MHz and below, and 1.5MHz and above. The case where lowpass and highpass filters are combined is illustrated by the frequency response given in **Fig. 6**. The two curves cross at the frequency where they are both at their cut off frequency (–3dB point).

Diplexers are valuable because the impedance at the common port remains constant across the band. This is true of a diplexer input, because if the signal frequency is outside the passband of one filter, it must be inside the passband of the other. The source sees a constant impedance, so its voltage does not change with frequency.

Applications for diplexers include mixer output impedance matching. Mixers need to see a constant 50Ω across a wide bandwidth at their output terminal. This constant bandwidth should extend beyond the input signal and local oscillator frequencies. If the mixer output terminal is connected to a low frequency amplifier stage, the impedance that its sees may be nothing like 50Ω at radio frequencies. A constant impedance can be realised by placing a diplexer with a lowpass filter between the mixer and amplifier, and a highpass filter to a 50Ω dummy load. Signals at frequencies outside the amplifier's range will be terminated, via the highpass filter, in the dummy load.

A diplexer can be designed using tables of normalised values, or by using filter synthesis computer programs such as *Filtech Professional* [2]. ■

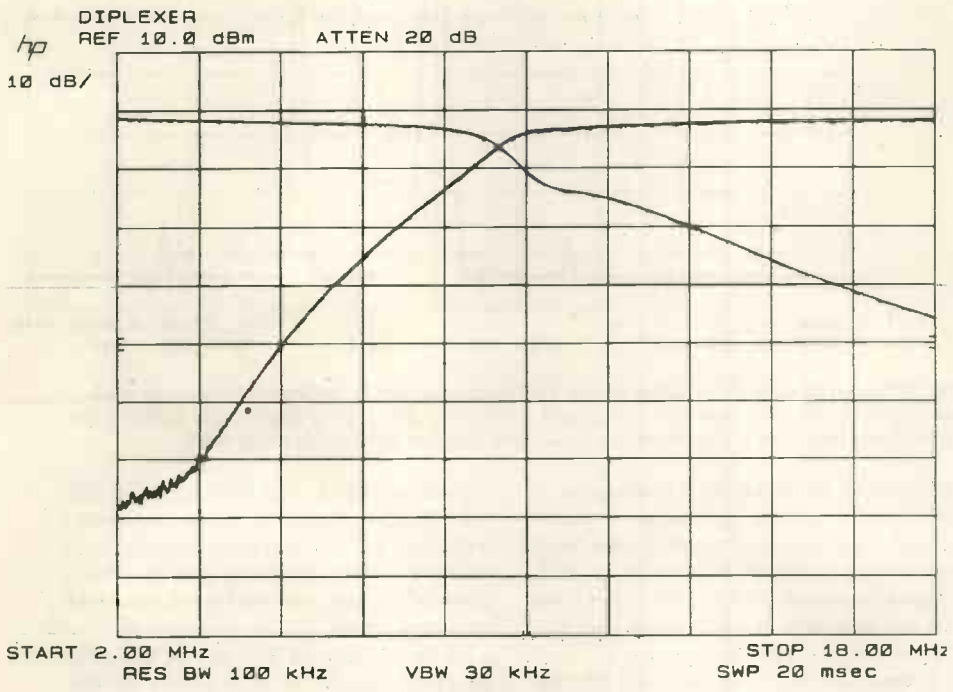


Fig. 6. Combined response of lowpass and highpass filters. The two curves cross at the frequency where they are both at their cut off frequency (–3dB point).

References

1. Mini-Circuits Ltd. Tel. 01252 835094
2. Number One Systems Ltd. Tel. 01480 461778

OCTOBER 1993
Wideband current mode amplifiers
Bandpass filter on a micro processor
Audio power chips put to the test

NOVEMBER 1993

DECEMBER 1993
Low cost spectrum analysis
IBM PC on a chip
Electronic power factor correction
The state of state mochines

JANUARY 1994

FEBRUARY 1994

MARCH 1994
Designer's guide to SMPS
Polyphase SSB receiver
Class A ultra-low distortion amplifier
Using the Smith chart

APRIL 1994
New wave microwave
Chips for audio noise reduction
Eight bit wireless duplex data link
Test generator for better video links

MAY 1994
Designer's guide to optoelectronics
Ultra-low distortion test oscillotor
Working with current mode amplifiers

JUNE 1994
Maintain control with RS232
Designer's guide to selcall
Synchronous alternative to PLLs?
Picking up on wireless LANs

JULY 1994
New look to amplifier design?
Sorting signals from noise
Using Hall to good effect
Precision op-amps: First ever mass review

AUGUST 1994
The data path to multimedia
Applying FPGA
Designing combiners and splitters
Charting Smith's computer world
Low power switch mode psu
Self-build teletext card for the PC

SEPTEMBER1994
Circuit design for RMS measurement
Power solutions to supply problems
The ultimate slew rate?
Parolle port for data exchonge
Easy acquisition under Windows?
Direct conversion SSB receiver

OCTOBER 1994
Signal processing at microwave frequencies
New circuits for one-chip function generators
The best schematic under Windows?
Feed forward beats feedback audio?

NOVEMBER 1994
Transformerless LCR bridge
Spice-Circuits by design
Superconductor evolution
Magnets for storage and switching

DECEMBER 1994
Communicating underground
Digital sines and cosines
Electrolytic rf detection
Maximising monopole bandwidth
Harmonic effects
Miniature rf link for remote control

BACK ISSUES

Back issues of Electronics World are available, priced at £2.50 in the UK and £3.00 elsewhere, which includes postage. Please complete the coupon and send with correct payment to: Electronics World, Quadrant House, The Quadrant, Sutton, Surrey, SM2 5AS.

Note that all issues are subject to availability and please allow 21 days for delivery.

Issue (Month/Year)	Quantity	Price	Total
		Total Order	

Name

Address

Postcode

Telephone

Method of payment (please circle):
Access/Mastercard Visa Cheque PO
Cheques payable to Reed Business Publishing
Credit Card Number
☐☐☐☐ ☐☐☐☐ ☐☐☐☐ ☐☐☐☐

Expiry Date

Signed

Having described his tuner and decoder card for loading teletext data directly into a pc, Laurence Cook now discusses the software needed to access the teletext information via the pc's com port.

Programming for teletext on the pc

PCBs and software

Silk-screened teletext adaptor pcbs together with eprom firmware and terminal software on disk are available. Details of the circuit for the adaptor, which features a video output for use with a monitor or multi-media, were presented in the August 1994 issue.

The board is double sided, with plated-through-holes, and has a gold-plated edge connector to fit an 8-bit pc ISA bus slot). It has a silk screened component legend. Terminal software on disk allows teletext data to be displayed on the pc's monitor.

Originally, the pcb and software package was £65 inclusive, but the author has reduced this price to £45 inclusive due to demand. Send your cheque or postal order to L. Cook, 9 Goose Cote Hill, Bolton, Lancashire BL7 9UQ. Overseas readers please add £5 to cover extra postage. All enquiries relating to the adaptor should be accompanied by an sae and sent to Laurence at the above address – not to *EW+WW*. Laurence's telephone and fax number is +44-01204 307293.

The design published in August *EW&WW* for a pc card teletext adaptor has created a good deal of interest. This follow-up is intended to provide you with enough information to program the adaptor, by describing the command set and formats used to control the tuner and teletext processor.

Before describing how to communicate with the adaptor, it is worth mentioning the answer to the most frequent query I have had relating to the adaptor – "How do I set up the card for optimum reception?" The answer is simply "you don't". It is supplied already set up for optimum results. There are no adjustments on the card, apart from the selection of com port and irq line. Even programmers can build the card, provided they can solder properly.

So how is teletext information made available to the pc? Simply via a standard serial com port using conventional asynchronous data on a row-by-row basis. It has a default bit rate of 9600baud (more on this later) just as if it had come from a modem or any other similar type of device.

The only quirk is the protocol used to specify and to encapsulate the data. Why does the data have to be supplied in this way, you may well ask? The answer is that the transmission system deals with 'rows' – which most people would call lines – of data. A 'page' of data, i.e. a screenful is 24 rows, cannot contain blank rows. This practice is sensible, since empty rows of forty spaces are a waste of valuable bandwidth.

So whereas, for example, a vdu might send two line-feed characters to include a couple of blank rows on a page, the broadcast teletext system simply omits to send those rows.

Normal pages, as seen on a domestic television receiver, comprise twenty four rows, numbered 0 to 23. The top row on the screen is special, and is called a header. It is row 0, and contains 32 characters for display (1 to 23 contain 40 characters each), the other 8 characters being used to identify the page to which the row belongs.

A 'page' of teletext is part of a 'magazine'. What we see as page 601 for example is actu-

Teletext adaptor command set

This is the command set and responses for the adaptor using the following convention:

- STX, EOT, etc, are ascii control codes, e.g. STX is 01_{16}.
- Strings in quotes are literal, e.g. 'BC' is 42_{16}, 43_{16}.
- Commas are included for clarity only and are not used.

Function	Command	Response	Comment
RESET	SOH,'Z'	CF2OOO	Ver. 5.19
CHANNEL	SOH,'T',NN	SOH,ACK,'T',EOT	NN = 21 to 69
HEADERS ON	SOH,'H+'		
HEADERS OFF	SOH,'H-'		
SELECT PAGE	SOH,'P',ppppssss, EOT	SOH,ACK,'P',EOT	s Is subpage
SEND TESTPAGE	SOH,'P',' FFFFFFF',EOT	<Reset sequence>	page from ROM
SET BAUDRATE	SOH,'B',n		n=1 for 1200 n=2 for 2400 n=3 for 4800 n=4 for 9600 n=5 for 19200

Received data formats are as follows:

HEADERS	SOH,'H',N,STX,<40 characters>,ETX	n=magazine represented as an ASCII digit
PAGES	SOH,'P',ppppssss,STX,' ',<40 chars.>for row zero r,<40 characters>r is (row+20) 7F HEX,EOT	page ends here

ally page 01 of magazine 6. This means that there are up to eight broadcast magazines. Zero to seven, you might think. No. They are referred to as magazines 1 to 8, but magazine 8 is number 0 while magazines 1 to 7 are numbered 1 to 7. This was chosen because the 3-bit binary number of a magazine, combined with the 5-bit binary number of a row, nicely fits an 8-bit byte which is contained at the start of each row transmitted. By choosing this scheme, the broadcasters can, and do, interleave rows from different magazines in a time division multiplex way, so improving page access time.

Luckily for the applications programmer, the adaptor sorts all this out and delivers a row prefixed with the appropriate number, as will be clear later. Content formats of rows, particularly those containing text and graphics, are best understood by referring to the Broadcast Teletext specification of September 1976.

Commands accepted by the adaptor are shown in the panel.

Flow control

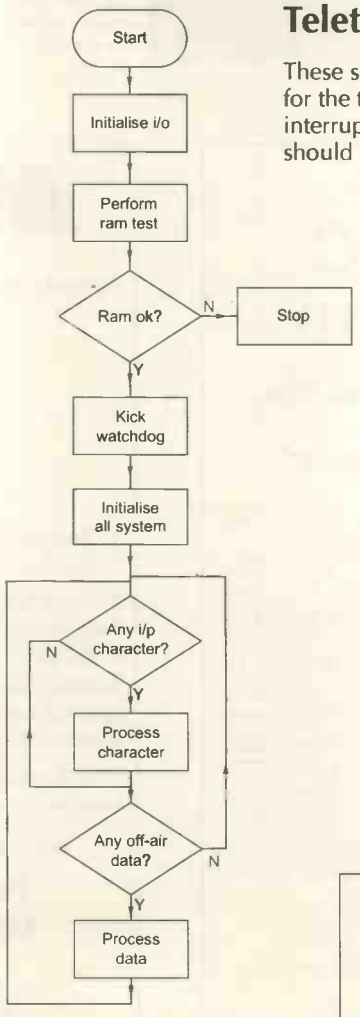
The adaptor uses out-of-band flow control. That simply means that instead of embedding XOFF (transmission off) and XON (transmission on) characters in the data stream, the modem control lines rts (request to send) and cts (clear to send) are used. These are hardware handshake lines that ensure data is not lost in either direction.

When programming the uart on the card, remember to have regard to the appropriate command and status bits in the relevant registers; unless of course you are using a comms library from C, in which case just call the pertinent functions.

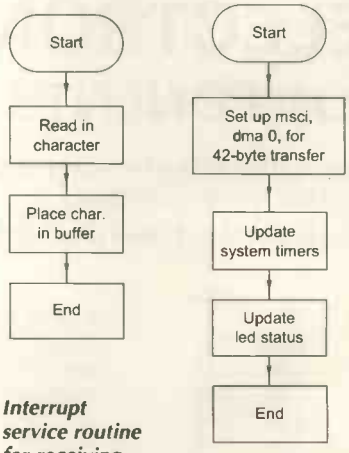
On the subject of uarts, note that the default rate is 9600baud and the data is asynchronous with 8 bits plus 1 stop bit and no parity. Also, you might have problems if you reprogram the

Teletext adaptor software flow

These simplified diagrams outline software flow for the teletext adaptor. Since the system is interrupt driven, the charts are discontinuous and should be treated as a guide only.

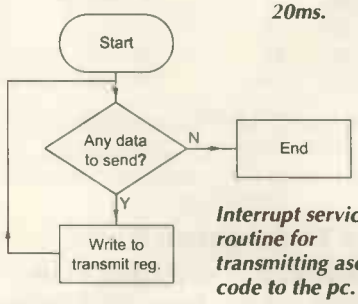


Main code flow for the teletext adaptor.

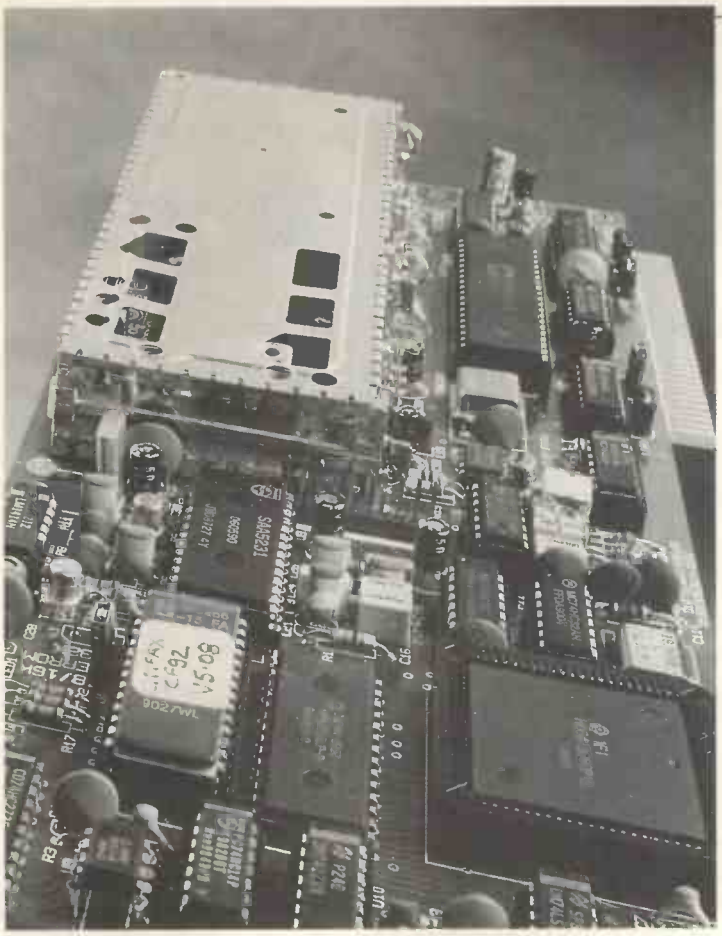


Interrupt service routine for receiving ascii from the host pc.

Frame synchronisation routine, used once every 20ms.



Interrupt service routine for transmitting ascii code to the pc.



Teletext adaptor for the pc incorporates a synthesized tv tuner and takes single 8-bit slot.

adaptor baud rate but forget to do the same for the uart. Of course, the two must always be in step for correct operation.

Throughout this short article, references to broadcasters can of course be widened to include cable operators. I have just subscribed to cable tv and I am amazed at the amount of worldwide data entering my home via teletext. I wonder how long it will be before the opportunities for distribution of information via telesoftware are fully realised

Hardware update

Since I wrote the article describing my teletext adaptor for the pc in the August issue, Hitachi has introduced a new addition to the 64180 microprocessor family called the *HD64180S2CP10*. This is cheaper than the *HD64180SCP10* used in the original adaptor design. It should be a drop-in replacement for it, but I have not yet evaluated it.

The antenna socket on the *FQ844* tuner module needed a small flat filing on it in order for it to fit through one of the pc enclosure's expansion board access holes. There is now a new tuner called the *FQ916ME/LIF* whose antenna socket fits without modification. I am currently evaluating this part, and so far, all indications are that this is a drop-in replacement. As a bonus, it is also cheaper. ■

KESTREL ELECTRONIC COMPONENTS LTD

☆ All items guaranteed to manufacturers' spec.
☆ Many other items available.
'Exclusive of V.A.T. and post and package'

	1+	100+		1+	100+
EPROMS			**STATIC RAMS**		
27C64-15	2.00	1.45	62256LP-10	3.00	2.15
27C128-15	2.40	1.80	6264LP-10	2.10	1.40
27C256-15	2.20	1.65	MM58274CN	4.90	3.75
27C512-15	2.20	1.65	ULN2003A	0.45	0.25
27C010-15	4.00	2.75	LM311N	0.30	0.18
27C020-15	6.00	3.99	LM555	0.30	0.18
27C040-15	8.60	6.45	MAX232	1.35	0.88
80C31-12	2.10	1.65	7406	0.35	0.23
80C32	3.00	2.40	7407	0.35	0.23
80C85ARS	2.90	2.30	74HCT244	0.35	0.27
82C55-5	2.40	1.55	74HC245	0.35	0.27
D8748H	4.30	3.35	74HC373	0.35	0.26
D8749H	4.40	3.45	74HC374	0.32	0.26

74LS, 74HC, 74HCT Series available
Phone for full price list
All memory prices are fluctuating daily, please phone to confirm prices

178 Brighton Road,
Purley, Surrey CR8 4HA
Tel: 081-668 7522. Fax: 081-668 4190.

CIRCLE NO. 121 ON REPLY CARD

MEJDAF Europe Ltd

*Quartz Crystals	32.768 KHZ, Watch 6mm tubular ±20ppm	£0.25
	2.097152 MHZ HC49 ±25ppm	£0.99
	3.579545 MHZ HC49 ±25ppm	£0.52
	4.149304 MHZ HC49 ±25ppm	£0.52
	4.433619 MHZ HC49 ±25ppm	£0.52
	5.068800 MHZ HC49 ±25ppm	£0.52
	6.000000 MHZ HC49 ±25ppm	£0.52
	6.144000 MHZ HC49 ±25ppm	£0.52
	10.000000 MHZ HC49 ±25ppm	£0.52

★ **'Engineer'** brand tools for Electronic Industry, professional and hobbyist.

★ **'Pro's-Kit'** brand tool-kits

Example, Butane torch soldering kit in a foam-lined case comprising of torch, solder, soldering tips, cutter, plier..... **£18.00**

Example, Electronic tool-kit comprising of a good digital multimeter, soldering iron, desoldering tool, pliers, cutters, screwdrivers, nut-drivers, adjustable wrench and many other tools..... **£42.34**

***PLUS** a wide range of active and passive components including Japanese transistors, power transistors and IC's.

Callers welcome – we are open Monday to Saturday 9 to 5.30pm.

Prices quoted are exclusive of VAT and carriage.

MEJDAF EUROPE LIMITED
196 Preston Road,
Wembley, Middlesex HA9 8PA
Tel: 0181 904 9671
Fax: 0181 904 9546

CIRCLE NO. 122 ON REPLY CARD

LETTERS

Letters to *"Electronics World + Wireless World"* Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS.

Compulsive comment

As a compulsive audio-project constructor and potential user of ideas offered by Graham Nalty (*Letters*, December) I should like to say that a critical feature that distinguishes Douglas Self's amplifier from Graham's and other offerings is that of simplicity.

Exclusion of power supply regulation is a good start. Projects invariably provide the opportunity for the designer to offer components, multiple pcbs and often an upgrade service involving high-priced items and materials from what is becoming an array of audio boutiques. Moreover, these entrepreneurs tender a variety of 'improvements' to other people's designs with a similar range of expensive bits and pieces.

I can say that few projects have given as much satisfaction during construction and practical use as the D Self amp. The pcb alone is far superior to most encountered previously and the audible results are very acceptable.

I qualify that last point by stating that I do not enjoy the acute aural sensitivity of many of my contemporaries and judge by the effect of listening for substantial periods without fatigue.

Certainly, the generously rated components used at moderate domestic levels barely get warm and to that extent I am now installing four of the five boards built to date into one case. Current fashion dictates separate amps for each driver (plus the sub-woofer in the floor) and it is sensible to have them all at the same sensitivity. Moreover, the existence of logic decoders, and the novelty of effects available calls for even more amps and speakers, so there is no end in sight at present.

EW + WW has maintained its long-standing pre-eminence in sponsoring only projects that will stand the critical test of time. Long may it continue so to do.

Hugh Haines
Sunderland

Unacceptable terms

I note that Graham Nalty (*Letters*, December) sees fit to offer a set of suggestions for improving the class-B amplifier design that I presented in my series *Distortion in Power Amplifiers, EW + WW passim*. All these modifications are supposed to give 'improved sound quality' a phrase which Mr Nalty chooses not to define, but which is left so vague as to be wholly unacceptable.

If Mr Nalty is unable to specify what effect his recommendations will have more closely than this, then it suggests he does not know himself.

The methodology used in the design in question, has, I think, been explained in greater detail than for any amplifier ever before. This has not dissuaded Mr Nalty from choosing to ignore the theoretical arguments, practical data and logical reasoning that I have tried to set out; he has simply sailed straight into a tinkering session based on reciting the usual old dogmas of subjectivism, which I suggest are by now becoming very tired indeed.

I do not think my amplifier is incapable of improvement. Indeed, having given the conventional architecture a fairly thorough workout, I have thought up some very interesting improvements in the last few months. But I am quite certain that stolidly replacing components with more expensive ones – apparently for no other reason than because they are expensive – is not the way to do it.

Firstly, all the exhortations about replacing perfectly good carbon-film resistors with expensive fetish items may be disregarded.

Improvement of the sound by this sort of thing is flatly impossible. I wonder if Mr Nalty just happens to sell Holco resistors, as he apparently sells expensive speaker cables? As for the rest of it, I have raked through the comments looking for any nuggets of truth, with the results I give below:

Nalty suggests: "Try replacing R_1 with a polyester capacitor; or place a similar capacitor in parallel with R_2".

Better not, as Tr_1 must have a source of base current to work, so replacing R_1 with any sort of capacitor will stop the amplifier dead. A capacitor shunting R_2 will almost certainly cause hf oscillation. On the other hand, R_1, R_2 may be a typographical error for C_1, C_2, which has at least the advantage of making some sort of sense. However no performance improvement can possibly result.

"I would prefer the feedback resistor to be high enough to use a polypropylene capacitor for C_2, if this can be done without creating a high dc offset at the output... remove C_4 and C_5..."

I would prefer to see Mr Nalty refrain from this sort of irresponsible tampering, which he cannot have thought through. I do not know what sort of polypropylene capacitors he has in mind, but the largest size stocked by RS Components is 0.47µF. This implies that R_8 would have to be increased to about 2MΩ to maintain the same if response, and the resulting output dc offset would roam between ±10V, depending on transistor beta. Since a good deal of electronic design goes toward making sure that things do not depend on beta – which is often a wholly untrustworthy parameter – this hardly seems the way forward.

It is quite untrue that dc servos always sound awful, though it is certainly the case that they require some care in design. In the case of power amplifiers, however, I think I have demonstrated that if a ±50mV offset range is acceptable, neither servo nor dc trimmers are necessary, even if high-voltage low-beta devices are used for the input pair.

As for removing C_4 and C_5, please don't do it. C_4 provides signal feed-forward around the V_{be}-multiplier, and without it there may be enough phase-shift in Tr_{13} to cause instability. C_5, as I carefully explained, gives cleaner switch-off of the output devices and so reduces hf distortion. Am I to understand that Mr Nalty thinks that clean switch-off is a bad thing?

"There are audio transistors available which have smoother gain vs current graphs..."

Tell us what the part numbers are then. The basic transconductance linearity of a transistor (ie the I_c/V_{be} law) is fixed by physics and is about as negotiable as the law of gravity. If, however, this refers to beta variation with I_c, then the *MJ802/4502* have pretty much the same beta-variation as most large power devices; Normalised h_{FE} varies by a factor of about 4.5 over the I_c range 30mA-10A. As the published series of articles showed, this materially affects thd into 4Ω loads or lower only. Mr Nalty's *MJ11016* shows a variation factor of 7.7 over the same I_c range, so his point seems somewhat obscure.

"The Darlington output arrangement is the best..."

In some respects it certainly is, but such a flat statement is misleading. *Distortion in Power Amplifiers* showed unequivocally that the CFP output stage has significantly better linearity and much more precise

Sine post

Noting that Ian Hickman is interested in the study of waveforms ("Harmonising theory with practice", *EW + WW*, December, pp.98-1002), I wonder what he might have to say regarding the initiation of sinusoidal waveforms in simple series *L*, *C* and *R* circuit, by application of a step function of voltage to the combination.

Why are the voltage waveforms generated across the elements sinusoidal?

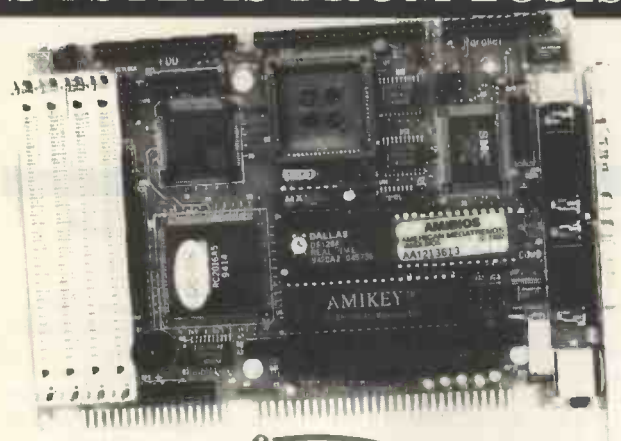
When a coil of wire is rotated between the poles of a magnet, it is obvious that the generated waveform should be sinusoidal, because the rate of change of magnetic flux linkage producing the voltage, is proportional to the sine of the angle of rotation of the coil. But there seems no easy physical property of the series *L*, *C* and *R* combination explaining why their voltage waveforms should be sinusoidal.

I know of course that we can prove, mathematically, via the solution of a differential equation for the circuit, that they should be so. But I am left wondering about the physical reasons.

Peter Dawe
Oxford

Ian is to reply to these comments in a future article.

COMPONENTS & SYSTEMS FROM IOSIS



iosis

INDUSTRIAL SPEC COMPONENTS AND SYSTEMS

386SX-40 All-in-one CPU Board on PC half card *from £215.* Requires only display adapter and RAM to complete the core of a PC-compatible system. PC/104 or ISA bus expansion. PC/104 display adapter *from £135.* Desktop LCD mono VGA monitor with display adapter and passive back-plane *from £499.* Please enquire for complete systems. *Prices exclude VAT and carriage.*

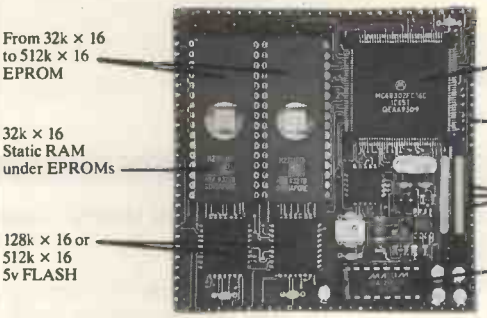
2c Chandos Road, Redland, Bristol BS6 6PE, UK

Tel: 0117 973 0435 Fax: 0117 923 7295

CIRCLE NO. 123 ON REPLY CARD

The EM68

68000 Embedded OEM Module



Powerful, Practical and Sensibly Priced

The CPU is Motorola's 16 bit 68302, a highly integrated 68000 processor running at 16Mhz. This processor has 3 full high speed serial ports operating in UART, HDLC/SDLC, BISYNC or DDCMP modes. It also has DMA channels. Interrupt controller, 28 parallel I/O lines 2 16 bit timers with compare and capture, Watchdog timer and low power (standby) modes. (We can supply the MC68302 Data Book.)

The Memory Up to 1M byte of EPROMs – 1M byte of FLASH EPROM and 64k Bytes of static RAM.

The EM68 Expandable to 16M byte, the EM68 is constructed on a Multilayer PCB with full power and ground planes and has a small 7.62cm^2 footprint.

Prices range from £255.50 (1 off – 1M Byte FLASH) down to £95.00 (100+ No FLASH)

Our Catalogue lists products based on the 64180, 80C31, Dallas 80C320, 80C552, 80C188 processors, and a wide range of peripheral modules, A/D, D/A, Serial, Opto, Relay, Transistor drive, Stepper drive, Thermocouple etc. with power supplies, backplanes and cases. Request a copy today.

Devantech Ltd
INDUSTRIAL ELECTRONIC CONTROLS

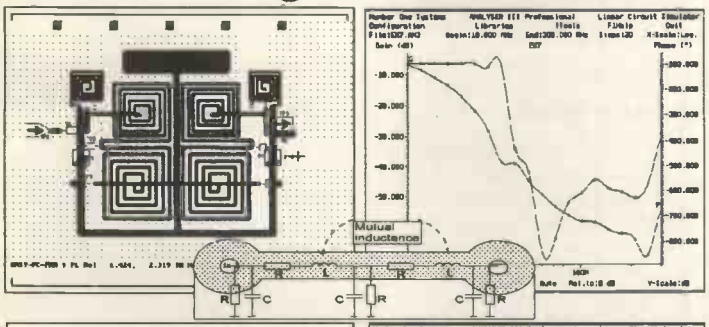
Units 2B-2C, Gilray Road, Vinces Road Industrial Est, Diss, Norfolk IP22 3EU, UK.
Tel: +44 379 644285
Fax: +44 379 650482

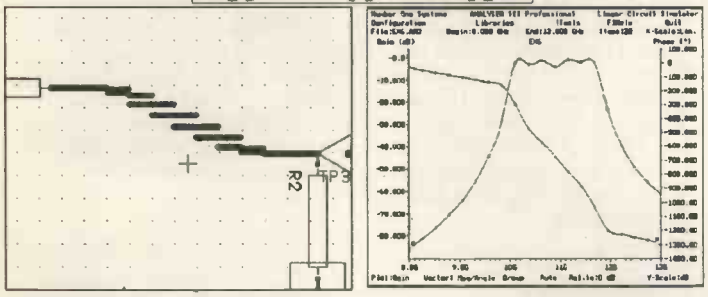
CIRCLE NO. 124 ON REPLY CARD

See us on Stand A107 at ICAT 95 (CADCAM) Show, NEC 7-9 March

Electronic Designs Right First Time?

NEW! - LAYAN - Affordable Electromagnetic Simulation





Only £495!

Visa, Delta, Switch, MasterCard and American Express welcome

Affordable Electronics CAD

LAYAN: Electromagnetic Layout Simulator. Links to EASY-PC Pro' XM and ANALYSER III Pro'.	**£495.00**
EASY- PC Professional: Schematic Capture and PCB CAD. Links to ANALYSER III and PULSAR.	**From £195.00**
PULSAR: Digital Circuit Simulator	**From £98.00**
ANALYSER III: Linear Analogue Circuit Simulator	**From £98.00**
Z-MATCH for Windows: Smith Chart based problem solving program for R.F. Engineers	**£245.00**
FILTECH: Active and Passive Filter design	**£145.00**
EASY- PC: Entry level PCB and Schematic CAD	**£98.00**

Technical Support FREE for life! Prices exclude P&P and VAT.

Special discount schemes for education

Number One Systems Ltd.
Ref: WW, Harding Way, St. Ives, Huntingdon, Cambs. PE17 4WR, UK.

For Full Information Please Write, Phone or Fax.

Tel: +44 (0) 1480 461778
Fax: +44 (0) 1480 494042

CIRCLE NO. 125 ON REPLY CARD

quiescent control, and in many applications would probably be the preferred approach. Integrated Darlingtons give truly awful quiescent stability, and I have yet to hear of a good reason for using them in audio amplifiers.

"Constant current sources are good design." The simple *RC* decoupling applied to bias chain R_{21}, R_{22} could indeed be replaced by a constant-current diode. One minor snag is that the cost is about thirty times that of doing it my way. In addition, an *RC* network can be relied upon to maintain effectiveness up to high frequencies, which is in general not true of 'electronic' decoupling methods.

"Cascode transistors above the collectors of Tr_2, Tr_3 and Tr_4... offer further scope for improving sound quality"

Wholly untrue, I'm afraid. Cascoding the input pair $Tr_{2,3}$ has the potential to improve negative-rail psrr, but the best rationale for doing it is to allow the input pair to be low-V_{ce}, high-beta types, which will reduce the range of dc offset at the output. DC is not usually considered an audible phenomenon.

Cascoding the vas Tr_4 is redundant as it is already linearised by Tr_{12}, and in any case cascoding alone is pointless because the vas collector impedance cannot be much raised when it is subject to the non-linear loading presented by the output stage. This was discussed at some length in the articles, and I rather wish Mr Nalty had read it.

I am unable to comment on the Apex and Virtuoso designs, as we are not told where or when they were published. Perhaps Mr Nalty might like to make the circuitry available for critical examination.

Finally, Mr Nalty remarks that "every single component in the audio chain degrades the signal" which is simply not true. From this point of view most of them are blessedly irrelevant. Even in the power amplifier there are very few components that have a major effect on the audio performance. This is, after all, the glory of negative feedback.

Mr Nalty's criticisms are couched entirely in the language of subjectivism. There is now a growing consensus that a school of thought which in 20 years has been quite unable to offer a single piece of solid evidence in support of its beliefs need not be taken too seriously.

Douglas Self
London

Slew review

Douglas Self seems to believe I was criticising his work (*Letters*, December) rather than simply responding to anomalies raised in his articles.

I did not think it out of context to blame the input stage for the disparity in positive and negative slew since it is clear from the article that the primary effect of charge and discharge of C_{dom} is derived from the input stage.

It may be true that loading effects are influencing C_{dom} from the vas stage. But this was not really my point. I had prefixed my comment with the proviso "unless". Unless there were other mechanisms not alluded to, then the slow output devices would be responsible for the ultimate rate of slew.

In "Further complications" (High speed audio power, *EW + WW*, September, pp. 760-764) Self states that with certain values for R_4 and R_{13}, the slew rate is +37 and −52V/µs for class B operation and an 8Ω load.

So I assume that the output devices are now connected in place of the test circuit and that slew rate figures refer to an actual completed amplifier. If such is the case then, as I quoted before, the condition for slew rate is: maximum frequency at which the amplifier can deliver a voltage corresponding to its rated full power.

Given the condition stated in my letter, Self's amplifier would need to maintain full power to a frequency exceeding 200kHz.

An alternative way of expressing the bandwidth of an amplifier, without using slew rate, is that if 20kHz is to be the accepted upper frequency response then the amplifier should be capable of delivering this *open loop* ie without feedback. With feedback applied, the upper frequency cut-off should be at least 20kHz multiplied by the feedback loop gain so that for 30dB of feedback, the cut-off should be 600kHz or more.

I have made as close an estimate as possible of slew rate and the alternative expressions based on the *The Audio Handbook* by Gordon J King, pp. 47 and 103.

On a personal note, I have auditioned bi-polar amplifiers over the years and where possible obtained the frequency/power curves. For those amplifiers with 100W and over, the rate of roll-off – with few exceptions – occurs around the 15kHz mark. It has in fact become endemic, and some amplifiers from reputable stables with multiple output devices start to roll off as low as 12kHz, while claiming slew rates of 30V/µs or more. Clearly this is an anomaly, and yes, they do sound dull compared to the mosfet amplifiers – which is hardly surprising.

Self's amplifier is being advertised as usable up to 100W output. I had naturally assumed a high frequency penalty and had expected a qualification. As it stands the amplifier must remain the substance of things hoped for, and for me, the evidence of things not seen.

The mechanisms concerning C_{dom} can be found in J Linsley Hood's book *The Art of Linear Electronics*. Effects of the vas stage on C_{dom} – increasing its value by the stage gain to $(A + 1)$ – and an alternative position for C_{dom} to overcome the problems experienced by Self's circuit topography can be found here: pp.119 and 163 refers.

With respect to the question of linearity and mosfets, Self will be able to find in both the above reference books categorical statements that mosfets are more linear than bi-polars – and perhaps more importantly why this is so.

I believe that the statistical evidence is in favour of the mosfet since even the worst examples of the Hitachi cloned circuits exhibit very low levels of distortion, with little effort. By contraindication, many of the bi-polar circuits, using more devices, are barely managing distortion levels 10 to 100 times worse. In fact many amplifiers could hardly be classified as *hifi* by the agreed standard, almost as if distortion is to be welcomed. Self's amplifier is very much the exception I'm afraid.

Dealing with the question of psychoacoustics, Self must be privy to information that most us are not, since with all the work done over the years, we could have expected some of it to have trickled down into the audio world. I observe that no internationally agreed upper frequency hearing response has been established – or lower frequency response for that matter.

Sine wave expressions continue to be used for complex waves as does a criterion for testing amplifiers that has caused a division so great that there are now two distinct schools of thought (objectivity and subjectivity). That criterion is the double-blind listening test. Yet there seems to be no relevant technical paper to back it up, and main evidence appears to have been adapted from medical and scientific research methods using double blind tests. But the substance of those tests is based on an entirely different context. Exponents of this philosophy seem to believe that all properly-designed amplifiers sound the same, thereby at a stroke undermining all attempts by designers to improve circuit topographies, reduce distortion, and improve components.

I see no advance in the cause of psychoacoustics. But I do see the revival of the Zanzibar fallacy, the story of which can be found in King's book.

Self's last comment is rather terse. I suspect we have all played with circuits. Surely that does not put expertise into question.

V J Hawtin
Middlesex

Douglas Self replies

I can reassure Mr Hawtin that I am in no way outraged by his comments, but I am saddened that he found my writings somewhat less than lucid.

I stand by my statement that while an amplifier input stage is the primary determinant of slew-rate capability, it is vital to remember that current sourced or sunk by this stage must also be sunk or sourced somewhere else if it is to complete its circuit. This typically adds limitations that render the maximal slew-rates asymmetrical. Similarly, it is easy to overlook how current siphoned off into other stages e.g. via the input impedance of the output stage, which is naturally load dependent can degrade slewing.

Output stages do not have an inherent slew-rate limit, although they naturally have bandwidth limitations. Mr Hawtin is unclear about the difference between these two parameters; they are in no way interchangeable, and can be altered independently of each other in most cases. An output capability that changes with frequency is no guarantee that there is a slew-limiting problem; there are other ways this can come about.

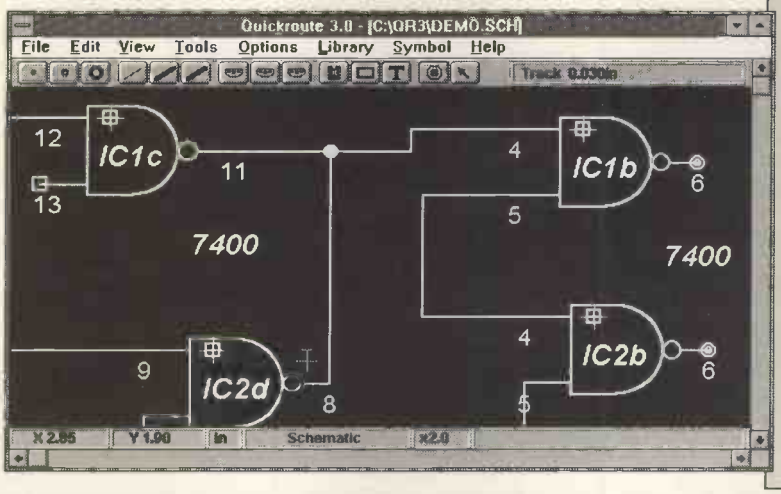
To move on to power fets, I am having some difficulty believing in the large body of "statistical evidence" that Mr Hawtin claims to have in support of his statement that mosfets are just as linear as bipolars, if not more so. Perhaps he will be good enough to let us see it, so we do not have to rely on his word? Or perhaps, like some other correspondents, he feels that to actually present evidence is in some way distastefully vulgar, and that it should merely be alluded to with a knowing smile.

'Hitachi-clone' mosfet amplifiers rarely seem to do better than 0.01% thd at 1kHz in practice, and I believe this to be determined very largely by the intrinsic Class B crossover non-linearity of these power devices. I think it would be very difficult to obtain less than 0.001% thd from mosfets in relatively straightforward circuitry, but this can be done routinely with bipolars if the correct design methodology is used.

Why Mr Hawtin should think that psychoacoustics is some sort of secret science I cannot imagine. Textbooks on the subject are available in any decent academic bookshop. A good introduction is

Quickroute 3.0

PCB & Schematic Design System for Windows 3.1



Announcing a new range of affordable, powerful Windows based PCB and schematic design packages from *POWER*ware.

DESIGNER £99 *

PCB and schematic design with all the new 'Easy-Edit' features and an Auto router!

DESIGNER+ £149 *

For larger PCB and schematic designs, adds Gerber and NC-Drill support.

PRO £199 *

Schematic capture, with integrated rats-nest generation and auto-router. Export net-lists for design checking.

PRO+ £299 *

Advanced schematic capture for management of larger schematics. Gerber import facility for file exchanging.

For more details, contact *POWER*ware, 14 Ley Lane, Marple Bridge, Stockport, SK6 5DD, UK.

*** Prices exclude VAT, post & packing**

Tel/Fax 061 449 7101

from £99*

CIRCLE NO. 126 ON REPLY CARD

SYSTEM 200 DEVICE PROGRAMMER

SYSTEM: Programs 24,28,32 pin EPROMS, EEPROMS, FLASH and Emulators as standard, quickly, reliably and at low cost.

Expandable to cover virtually any programmable part including serial EEPROMs, PALs, GALs, EPLDs and microcontrollers, in many different packages.

DESIGN: Not a plug in card but connecting to the PC serial or parallel port; it comes complete with powerful yet easy to control software, cable and manual.

SUPPORT: UK design, manufacture and support. Same day dispatch, 12 month warranty. 10 day money back guarantee.

ASK FOR FREE INFORMATION PACK

MQP ELECTRONICS Ltd.
Park Road Centre
Malmesbury, Wiltshire. SN16 0BX. UK
TEL. 0666 825146 FAX. 0666 825141

IRELAND	1-2800395
GERMANY	089/4602071
NORWAY	0702-17890
ITALY	02 92 10 35 54
FRANCE	1 69 30 13 79
SWEDEN	08 590 32185

Also from ELECTROSPEED UK

CIRCLE NO. 127 ON REPLY CARD

JPG Electronics

High quality stepping motor kits (all including stepping motors) 'Comstep' independent control of 2 stepping motors by PC (Via the parallel port) with 2 motors and software ..... Kit £67.00
Ready built £99.00
Software support and 4 digital inputs kit £27.00
Power interface 4A kit £36.00
Power interface 8A kit £46.00
Stepper kit 4 (manual control) includes 200 step stepping motor and control circuit £23.00
We are now stocking a range of stepping motors and kits to drive them please ask for the stepping motor data sheet for full information.
Invertor toroidal transformers 225VA 10.5-0-10.5 primary 0-260-285 secondary £29.95
LEDs 3mm or 5mm red or green ..... 7p each
Yellow ..... 11p each
Cable ties, 1p each, £5.95 per 1000, £49.50 per 10,000
High quality photo resist copper clad epoxy glass boards

Dimensions	single sided	double sided
3x4 inches	£1.09	£1.25
4x8 inches	£2.75	£2.99
6x12 inches	£6.20	—
12x12 inches	£12.25	—

Rechargeable Batteries
AA (HP7) 500mAH £0.99
AA 700mAH £1.75
C 2AH with solder tags £3.60
D 4AH with solder tags £4.95
1/2AA with solder tags £1.55
AAA (HP16) 180mAH £1.75
AA 500mAH with solder tags £1.55
C(HP11) 1.8AH £2.20
D(HP2) 1.2 AH £2.60
PP3 8.4V 110mAH £4.95
Sub C with solder tags £2.50
1/3 AA with tags (Philips CTV) £1.95
Standard charger charges 4 AA cells in 5 hours or 4Cs or Ds in 12-14 hours+1xPP3 (1, 2, 3 or 4 cells may be charged at a time) £5.95
High power charger as above but charges the Cs and Ds in 5 hours. AAs, Cs and Ds must be charged in 2s or 4s £10.95
Nickel Metal Hydryde AA cells high capacity with no memory. 1000mAH £3.50
1200mAH £3.75
Special offers, please check for availability.
42 x 16mm dia 1.2v £1.45
Stick of 4 171mmx16mm dia with red & black leads 4.8v £5.95
Computer grade capacitors with screw terminals
87000uf 10v £1.95
68000uf 15v £2.95
10000uf 16v ..... £1.50, 58000uf 60v £4.95
7 segment common anode led display 12mm £0.45
LM337k TO3 case variable regulator ..... £1.95 (£1.44 100+)
GaAs FET low leakage current S8873 .... £12.95 each (£9.95 10+, £7.95 100+)
BS250 P channel mosfet £0.45
BC559 transistor ..... £3.95 per 100
74LS05 hex invertor ..... £10.00 per 100
Used 8748 Microcontroller £3.50
SL952 UHF Limiting amplifier LC 16 surface mounting package with data sheet £1.95
AM27S02 ..... £1.25 each 90p 100+
CD4007UB ..... 10p 100+ (6p, 1000+)
Sinclair light gun terminated with a jack plug and PP3 clip gives a signal when pointed at 50HZ flickering light with output wave form chart £3.95
DC-DC convertor Reliability model V12P5 12v In 5v 200ma out 300v input to output Isolation with data ..... £4.95 each or pack of 10 ..... £39.50
Hour counter used 7 digit 240v ac 50Hz £1.45
QWERTY keyboard 58 key good quality switches new £6.00
Airpax A82903-C large stepping motor 14v 7.5° step 27ohm 68mm dia body 6.3mm shaft ..... £8.95 or £200.00 for a box of 30
Polyester capacitors box type 22.5mm lead pitch
0.9uf 250vdc 18p each 14p....100+ 9p....1000+
1uf 250Vdc ..... 20p each 15p....100+ 10p....1000+
3.3uf 100vdc... 30p each 20p...100+ 15p..1000+
1uf 50v bipolar electrolytic axial leads ..... 15p each 7.5p ..... 1000+
0.22uf 250v polyester axial leads ..... 15p each 7.5p ..... 100+
Polypropylene 1uf 400vdc (Wima MKP10) 27.5mm pitch 32x29x17mm case ..... 75p each 50p ..... 100+
Philips 123 series solid aluminium axial leads - 33uf 10v & 2.2uf 40v ..... 40p each 25p ..... 100+
Philips 108 series long life 22uf 63v axial..... 30p each 15p ..... 1000+
Multilayer AVX ceramic capacitors all 5mm pitch 100v 100pf, 150pf, 220pf, 10,000pf (10n) .... 10p each 5p.....100+ 3.5p.....1000+
500pf compression trimmer 60p
40 uf 370vac motor start capacitor (dialectrol type containing no pcbs) ..... £5.95 or £49.50 for 10
Solid carbon resistors very low inductance ideal for RF circuits - 270ohm 2W, 680ohm 2W ..... 25p each 15p each 100+
We have a range of 0.25w 0.5w 1w and 2w solid carbon resistors, please send SAE for list
P.C. 400W PSU (Intel part 201035-001) with standard motherboard and 5 disk drive connectors, fans and mains inlet/outlet connectors on back and switch on the side (top for tower case) dims 212x149x149mm excluding switch £26.00 each £138.00 for 6
MX180 Digital multimeter 17 ranges 1000vdc 750vac 2Mohm 200mA transistor Hfe 9v and 1.5v battery test £12.95
AMD 27256-3 Eproms ..... £2.00 each £1.25/100+
DIP switch 8PCO 12 pin (ERG SDC-3-023) 60p each 40p...100+
Disk drive boxes for 5.25 disk drive with room for a power supply, light grey plastic, 67x268x247mm ..... £7.95 or £49.50 for 10
Hand held ultrasonic remote control £3.95
CV2486 gas relay, 30x10mm dia with 3 wire terminals, will also work as a neon light ..... 20p each £7.50 per 100

All products advertised are new and unused unless otherwise stated.
Wide range of CMOS TTL 74HC 74F Linear Transistors kits. Rechargeable batteries, capacitors, tools etc always in stock. Please add £1.95 towards p&p. VAT included in all prices.

JPG Electronics, 276-278 Chatsworth Road, Chesterfield S40 2BH
Access/Visa (01246) 211202 Callers welcome

CIRCLE NO. 128 ON REPLY CARD

the work, *An introduction to the psychology of hearing* by Brian Moore (Academic Press). It includes a section on psychoacoustics and *hi-fi* that illustrates why subjectivist notions are not necessary to explain the ear/equipment relationship.

Finally, I can make no sense of Mr Hawtin's repeated claim that all bipolar amplifiers have a bandwidth limited to 12 or 15kHz; since this is patently untrue, there is no point exploring the topic.

Doug Self

Heartfelt criticism

Recently one of my customers wrote to thank me for the immense pleasure and satisfaction he was experiencing when listening to music reproduced through an amplifier manufactured by my company. Immediately, not to fall foul of the Trade Descriptions Act, I had to contact him to tell him that, though my test equipment had confirmed that his amplifier did indeed meet its published spec, what he had said was a) merely his opinion, b) not supported by any form of scientific evidence or research, and c) almost certainly invalid anyway because his hearing was far too unreliable, non-uniform and too easily fooled to be relied upon for a meaningful value judgement.

He faxed me back to say that if I was going to talk such a load of old twaddle then, thank you very much, but he'd rather get on with listening to his own choice of music at his own choice of level. So would I.

Now a question for Phil Denniss and Douglas Self: what about the great symphonies, the playing of a lovingly-crafted violin, early morning bird song? You can't use a scope to explain why or how such things come in through our ears and touch our hearts... but it happens.

I tell you what I hear, you tell me I don't – although to 'prove' your prejudices you have to resort to derision, selective argument and syllogistic reasoning.

Presumably, as true objectivists, you must also deny the existence of beauty, or harmony, or perhaps even hunger as not being scientifically provable? Anyway, no more. I give in. Goodbye.

Jerry Mead
Mead & Company
Herts

Hand-shakey?

In the scores of pc-related I^2C implementations, nearly no one takes into account the fact that both the scl and the sda lines must be bi-directional, for handshake purposes.

The simple interface given in John Davies' article (*I^2C via the PC*, December, pp.994-996) might well work in some simple cases, but you will hit trouble as soon as you try to use e^2proms, or a-to-d/d-to-a converters; or the *PCD8584* bus controller (even as a slave).

Hardware must provide an input to read the state of the scl line, and the software must provide a way of reading that input.

Jean-Paul Brodier
Cuvry
France

Electrolytic detection

I noted the various electrolytic detectors described in George Pickworth's article (*Detection before the Diode*, pt I, December, pp.1003-1006). The early pioneers seemed to use platinum or lead in various diluted acid solutions. But I wonder if other materials and solutions were tried as detectors.

Some electrolytic rectifiers which may be of relevance are:

Al Pb	10:1 forward:reverse current
Al Fe	10:1
Cu Pb	12:1
Zn Pb	4:1

Also usable is zinc-aluminium alloy rod or cylinder with an iron tube.

In a saturated solution of phosphate of ammonium, current direction, alloy-to-iron results in film deposit on the surface of the alloy. Current direction, iron-to-alloy, results in reduction of film.

I think the claim was 85% efficiency, but would appreciate any comment related to this matter.

Unsigned
Middlesex

Coil question?

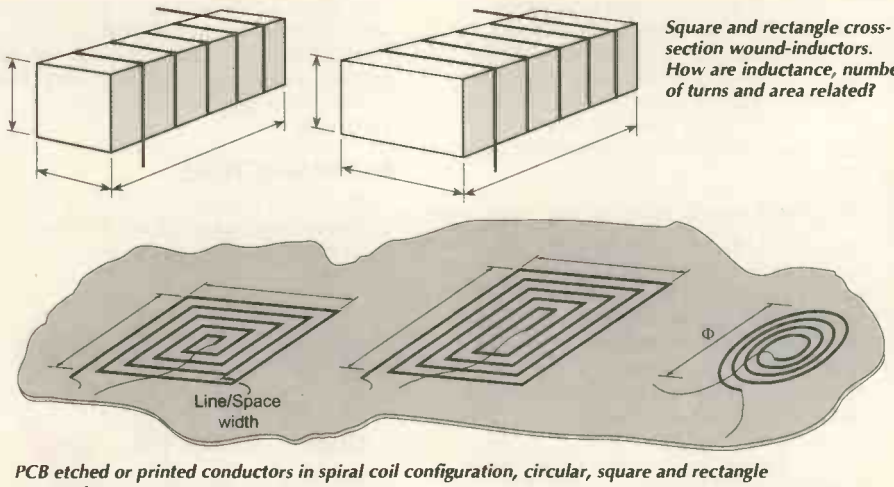
I am searching for several formulas involved in constructing inductors and coils using different configurations. I am familiar with formulas for calculating the number of turns, inductance, dimensions, etc, for single and multi-layer round inductors. However the project I am presently working on involves miniature coil construction using three-dimensional square and rectangle cores and two-dimensional pcb etched inductors.

I have searched through numerous reference books without success and would be most grateful for any help.

Formulas required are indicated in the accompanying figures. For example, I may wish to calculate the inductance from the number of turns etc or the coil design from a given inductance.

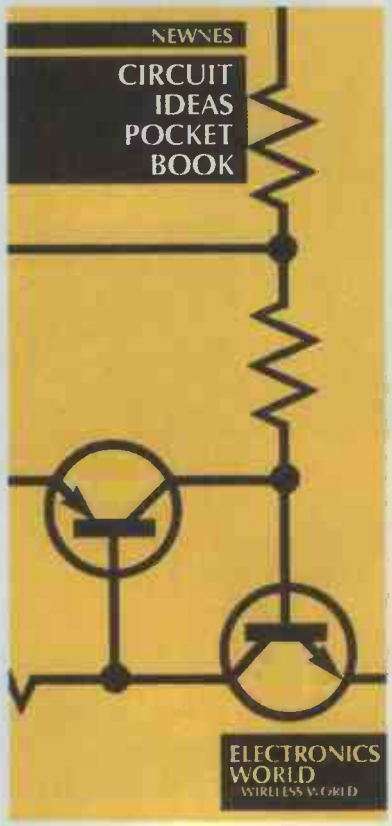
Any information will be greatly appreciated.

J P English
42 Matlock Road
Brighton, East Sussex
BN1 5BF



Square and rectangle cross-section wound-inductors. How are inductance, number of turns and area related?

PCB etched or printed conductors in spiral coil configuration, circular, square and rectangle geometries.



Free with next month's issue!

Free with all UK copies of the March issue of *EW+WW* is a special edition of the Circuit Ideas Pocket Book – a compilation of circuit ideas published in previous issues of *EW+WW*.

This unique book is worth £.4.95. To reserve your copy, fill in the newsagent's order form between pages 144 and 145.

on sale 23 Feb

The MICRO MODULE
A NEW LOW COST controller that gives you customisation for as little as £95 one off +VAT

For users of PCs, 8051 & 68000

and that's just the half of it!..

SAVE TIME... REAL TIME!
The Micro Module is a very low cost micro controller which is easily adapted to your exact requirements getting that job done quicker.

FEATURES
- 16/32 bit 68307 CPU for fast operation
- Up to 1 Mbyte of EPROM space onboard
- Up to 512Kbyte SRAM space onboard
- 32 Kbyte SRAM fitted as standard
- RS232 serial with RS485 option
- MODBUS & other protocols supported
- Up to 22 digital I/O channels
- 2 timer/counter/match registers
- I²C port or Mbus & Watch dog facilities
- Large Proto-typing area for user circuits
- Up to 5 chip selects available
- Program in C, C++, Modula-2 & Assembler
- Real Time multitasking Operating System
- OS9 or MINOS with free run time license option
- A full range of other Controllers available

ADDITIONAL FUNCTIONS
Additional functions are supported including: Analogue I/O, Digital I/O Serial ports, LCDs, Keyboards, Video, also a comprehensive range of signal conditioning including relays, AC & DC power switching, contact detectors, opto isolation, 4-20mA, thermocouples etc.

STARTER PACK AT ONLY £295+VAT
The Micro Module will reduce development time for quick turnaround products/projects and with the P.C. 'C' Starter pack allow you to start coding your application immediately, all drivers and libraries are supplied as standard along with MINOS the real time operating system all ready to run from power on.
The 'C' Starter pack includes : A Micro Module with 128 Kbyte SRAM, PSU, Cables, Manuals, C compiler, Debug monitor ROM, Terminal program, Downloader, a single copy of MINOS, extensive example software, and free unlimited technical support all for £295.

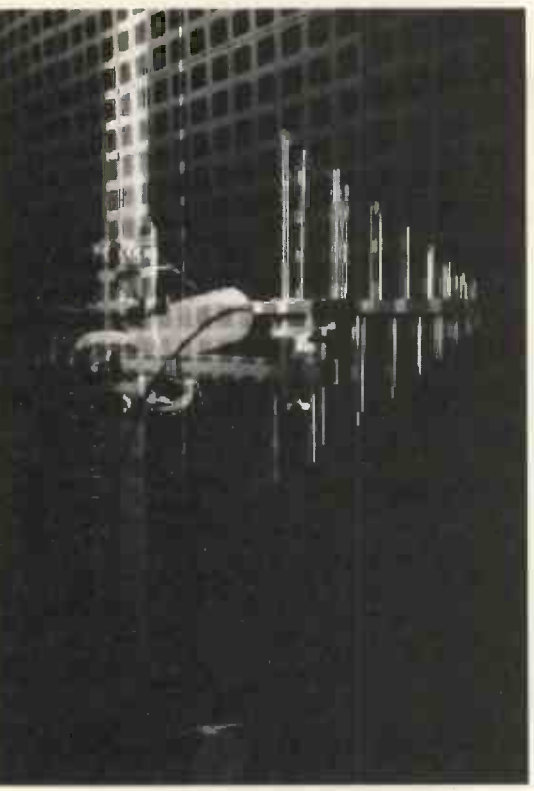
CUSTOM USE
The Micro Module is ideal for those one off jobs where you can add the special hardware interfacing required for your project, keeping costs down and making the final product unique to your company.

MANUFACTURE
CMS offer a full manufacturing facility to manufacture the Micro Module to your exact requirements even in low volumes.

CMS

Cambridge Microprocessor Systems Limited
Unit 17-18 Zone 'D',
Chelmsford Rd. Ind. Est.,
Great Dunmow, Essex. U.K. CM6 1XG
Phone 0371 875644 Fax 0371 876077

CIRCLE NO. 129 ON REPLY CARD



Norm Dye and Helge Granberg have shown how to develop the tools needed to design a small signal amplifier and how to determine source/load impedances. Here they bring all the tools together and suggest circuits that will realise those impedances. From the book **RF Transistors: principles and practical applications.**

Determining circuits for small signal amplifiers

Input impedance for the narrow band example where the match is for optimum gain and $S_{12} = 0$ (example 1) is plotted in **Fig. 1**. The Smith chart shows $\Gamma_S = 0.6$ at an angle of –156°. This is the value already determined from plots of optimum source and load reflection coefficients – see *EW + WW* January issue for more information – and the problem now is to take the 50Ω source and make it look like Γ_S.

The most common circuit is a low-pass filter configuration consisting of a shunt *C* and a series *L*. When using the Smith chart with shunt elements it can be used as an admittance chart, and when using it for series elements it can be used as an impedance chart. For this reason, Fig. 1 is plotted on a special Smith chart graph that simultaneously displays both normalised impedance and admittance circles.

The plot also demonstrates that a shunt capacitor having a susceptance value of $+j1.75$, which is the arc length from *O* to *A*, and a series inductance having a positive reactance value of $+j0.225$, arc length from *A* to *B*, will rotate the 50Ω source into the normalised value of 0.6 at –156°.

Calculating the actual values that give these normalised results at a frequency of 1GHz is a simple matter and the values turn out to be 5.6pF and 1.8nH.

Similarly, **Fig. 2** shows the output load impedance, also previously plotted. Again a network of shunt *C* and series *L* will be used to transform the 50Ω load to the desired load impedance represented by point *D* in Fig. 2. The arc from *O* to *C* calls for a shunt capacitor having a normalised susceptance value of $+j0.5$, and the arc from *C* to *D* needs a series inductance with a normalised value of $+j0.45$.

At a frequency of 1GHz, these can be realised by a shunt capacitor of about 1.6pF and a series inductance of 3.6nH (**Fig. 3**).

When S_{12} is not zero

For the narrow band, match-for-optimum-gain instance, where $S_{12} \neq 0$ (example 2) the output matching circuit is of course identical to example 1.

But slight changes in Γ_S and the shunt susceptance and series inductance are needed to transform the normalised 50Ω source impedance (centre of the chart) to the normalised value of Γ_S (**Fig. 4**).

Arc between *O* and *A* represents a shunt susceptance, i.e. parallel capacitor of $+j1.6$ and arc *AB* represents a series reactance, in this case a series inductance of $+j0.275$. Component values at 1GHz are 5.1pF and 2.2nH. The circuit is identical to that of example 1, shown in Fig. 3, except for the slight change in component values in the input matching network.

Specified gain < optimum gain

Example 3 is narrow band where specified gain < optimum gain and $S_{12} = 0$. The input circuit is shown in **Fig. 5**.

$A\Gamma_S$ was previously plotted on the –1dB gain circle on a Smith chart. Here it is re-plotted on a Smith chart showing both impedance and admittance circles. The value of Γ_S selected was 0.44 at an angle of +100°. Transformation of the 50Ω source impedance into the desired value represented by Γ_S is again most easily accomplished by using a shunt *C* and series *L*, seen in Fig. 5.

Arc *OC* represents a shunt capacitor having a normalised susceptance of 0.82 while arc *CA* represents a series inductance having a normalised reactance of approximately 1.15. These values are realised at 1GHz by a capacitance of 2.6pF and inductance of 9.2nH. The desired output load impedance is identical in examples 3 and 1, so the matching output cir-

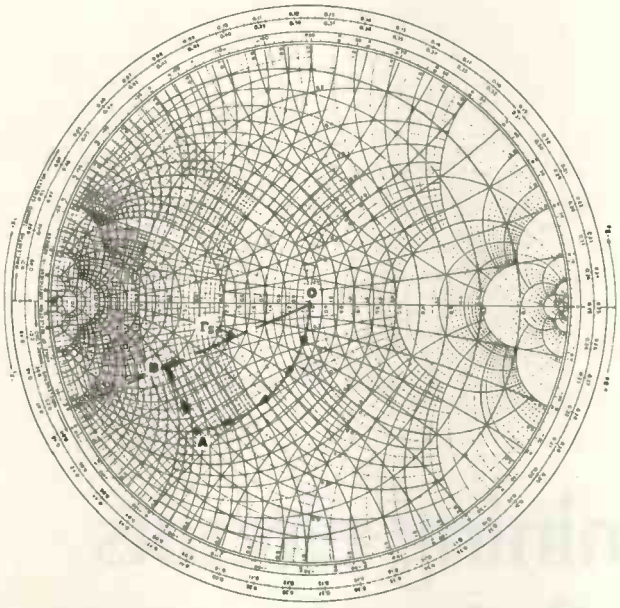


Fig. 1. Input matching for narrow band, match-for-optimum-gain, $S_{12} = 0$.

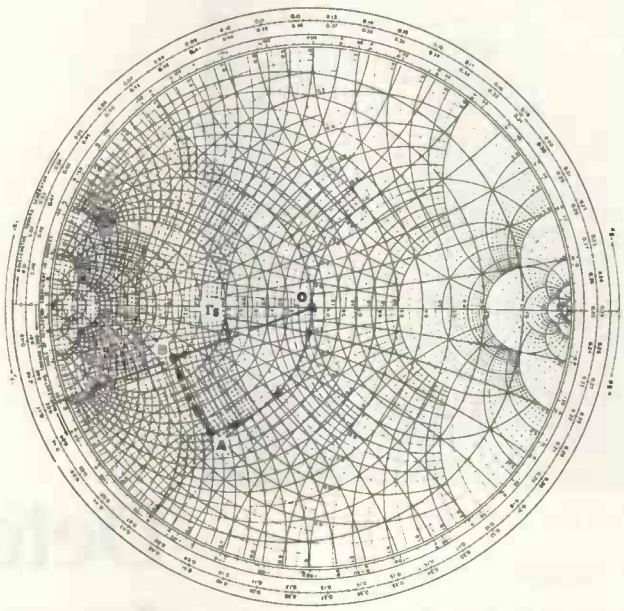


Fig. 2. Output matching for narrow band, match-for-optimum-gain, $S_{12} = 0$.

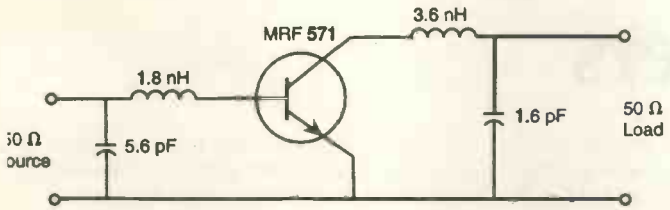


Fig. 3. Narrow band matching for best gain. Circuit can be used to match input and output.

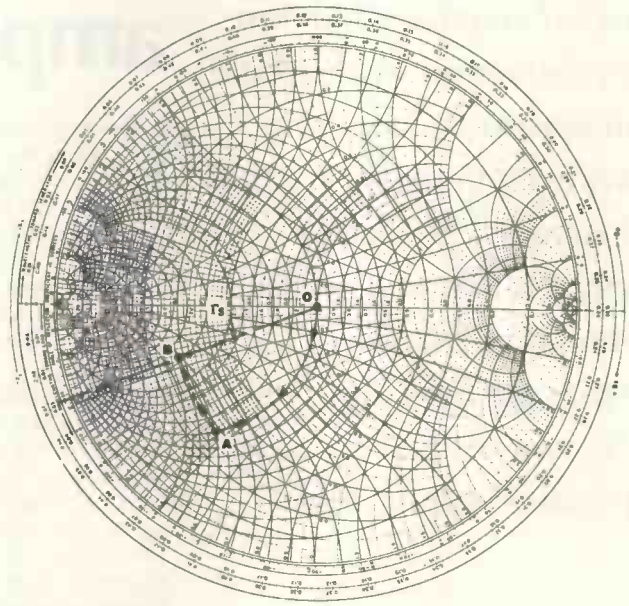


Fig. 4. Input matching for $S_{12} \neq 0$.

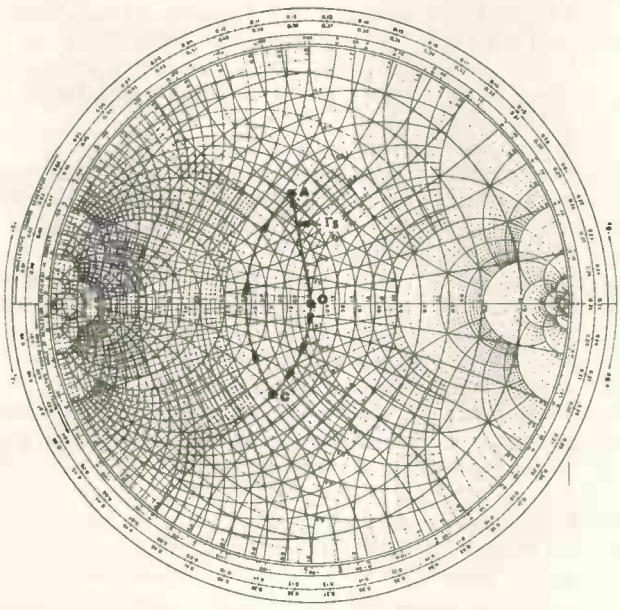


Fig. 5. Input matching for specified gain <optimum gain.

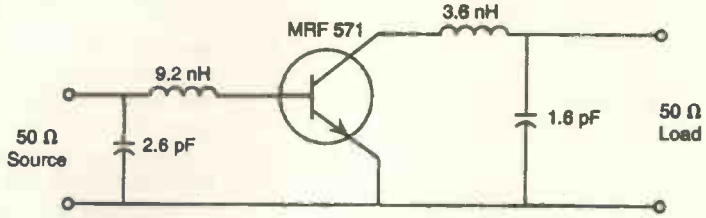


Fig. 6. Circuit for specified gain <optimum gain.

cuit is also identical to that shown in Fig. 2. **Figure 6** is the final circuit for this example.

Broadband design

Gain circles for the broadband design, example 4, have been plotted previously but here they are re-plotted in **Fig. 7** using the special Smith chart with normalised impedance and admittance circles. The objective is to devise a matching network that sits on the -4.5dB gain circle at 500MHz and at the same time on the +1.1dB gain circle at 1GHz.

In this instance, the *Mmicad* optimiser program can determine an appropriate network, consisting of a shunt *C* and a combination of series *C* and *L*. A similar solution could have been achieved by an iterative process of adjusting the circuit values until a combination is determined which meets both objectives.

At 500MHz the shunt susceptance moves along arc *OA*. The same capacitor will move

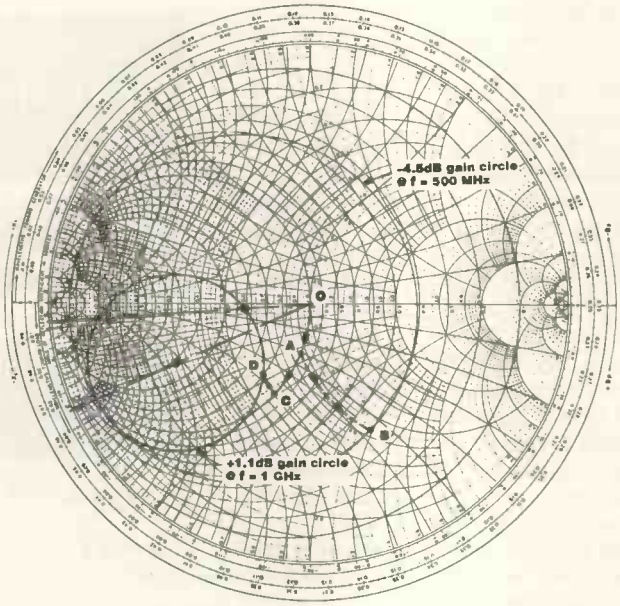


Fig. 7. Input matching for broadband design.

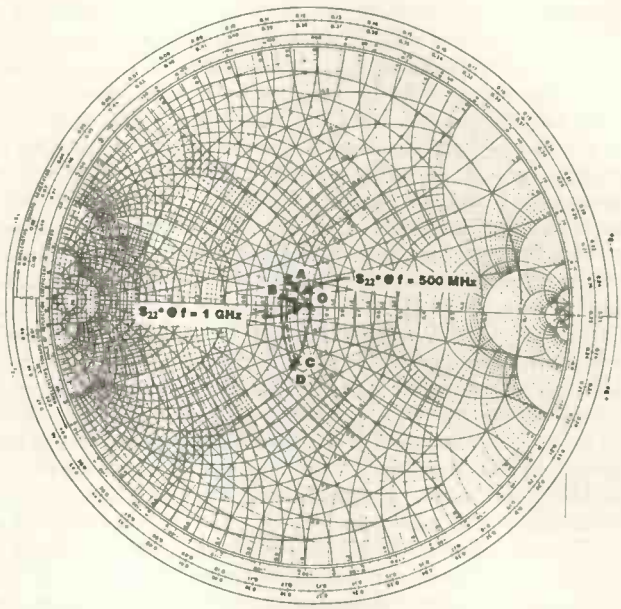


Fig. 8. Broadband design output matching.

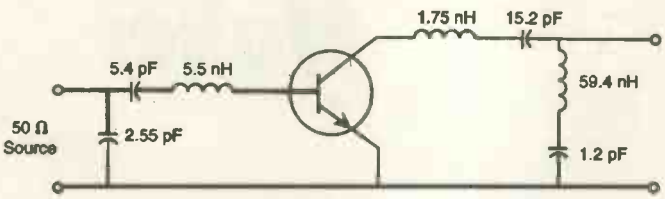


Fig. 9. Broadband design circuit.

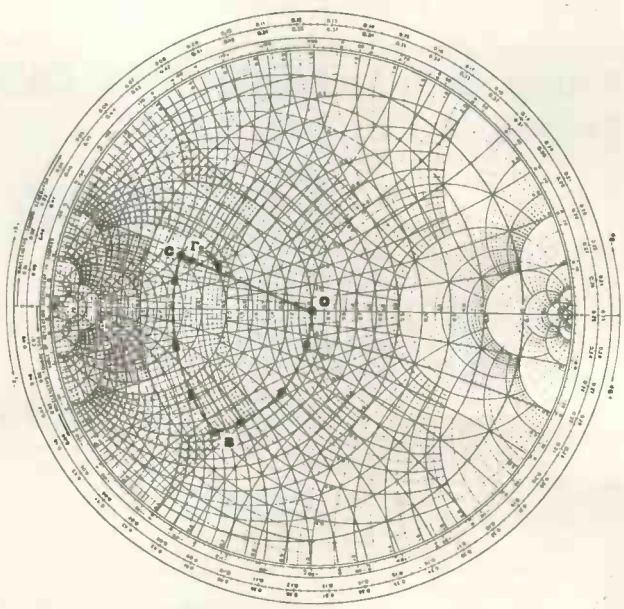


Fig. 10. Input matching for low noise.

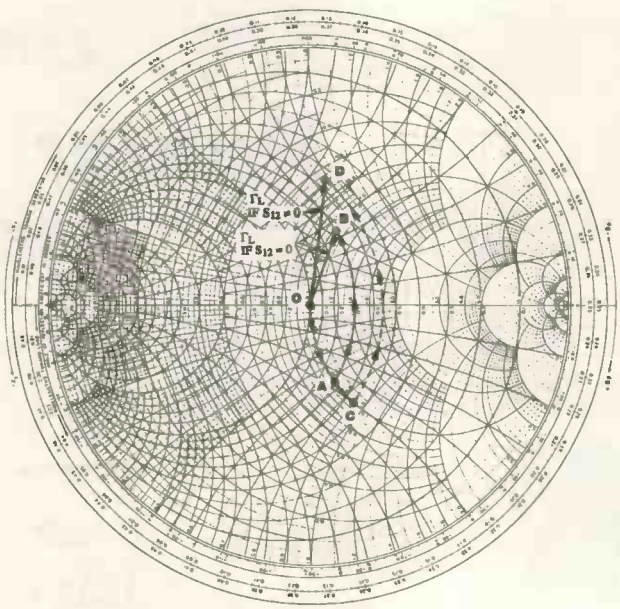


Fig. 11. Output matching for low noise.

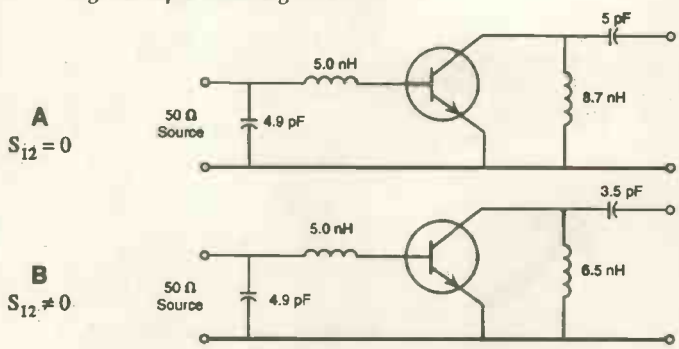


Fig. 12. Circuit configurations for low noise.

to C when the frequency increases to 1GHz. When the frequency is at 500MHz, the series network must move along arc AB while the same network must move from C to D at 1GHz.

Values that will achieve these objectives simultaneously are a shunt susceptance of $+j0.4$ at 500MHz, increasing to $+j0.8$ at 1GHz and an overall series reactance that is $j0.84$ at 500MHz but $+j0.09$ at 1GHz.

Component values that give the desired susceptance and reactances are a shunt capacitor of 2.55pF and a series capacitor of 5.4pF along with a series inductance of 5.5nH (**Fig. 9**). Because all the gain correction is placed in the input network, the output is the conjugate match, or S_{22}^* at each frequency, points plotted in **Fig. 8**. The problem now is to find a network that will simultaneously locate the matched load (O in the centre of the chart) at point A when f = 500MHz and at B when f = 1GHz. A shunt LC network with a series LC network is chosen such that the shunt network in Fig. 8 moves along the arc OC at 500MHz, but only moves from O to D at 1GHz.

Likewise, the series network moves the normalised line impedance from C to A at 500MHz, and moves the normalised line impedance from D to B at 1GHz.

Values of L and C that accomplish these objectives can be determined by solving relatively simple simultaneous equations relating the susceptances and reactances at the two frequencies of interest.

Actual values, along with the input network, are shown in Fig. 9.

Designing for low noise

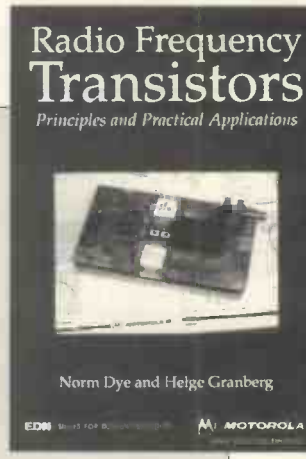
The value of Γ_S taken from a previous plot of the 2dB noise figure and 12dB gain has been re-plotted on the special impedance and admittance Smith charts used to determine graphically the impedance matching networks needed for a particular application (**Fig. 10**).

Matching is readily achieved by using a shunt capacitor to transform the 50Ω source from O to B. A series inductance finishes the match by transforming the value of B to the desired Γ_S, shown as C. Values of the shunt capacitor and series inductance that achieve the desired source reflection coefficient are 4.9pF and 5.1nH, **Fig. 12**, and output impedance matching is shown in **Fig. 11**.

The matching network, if $S_{12} = 0$, is a series capacitance and a shunt inductance that transforms the matched load first to A (series capacitor) and then to B (shunt inductance), or in the case of $S_{12} \neq 0$, to C (series capacitor) and then to D (shunt inductance).

So for $S_{12} = 0$, arc OA is a reactance of $j0.64$ which translates into a series capacitor of 5pF. Likewise, arc AB is a susceptance of $+j0.91$ which can be realised by a shunt inductance having a value of 8.7nH as shown in **Fig. 12a**.

If the measured S_{12} value is used, matching requires a reactance represented by arc OC and a susceptance represented by arc CD. These values are realised by a series 3.5pF capacitor and a shunt 6.5nH inductance, **Fig. 12b**. ■



RF Transistors: Principles and practical applications is available by postal application to room ***L333 EW+WW, Quadrant House, The Quadrant, Sutton, Surrey, SM2 5AS.*** Cheques made payable to Reed Books Services. Credit card orders accepted by phone (081 652 3614).

288 pages Hardback 07506 9059 3

Cost £19.95 + Postage £2.50

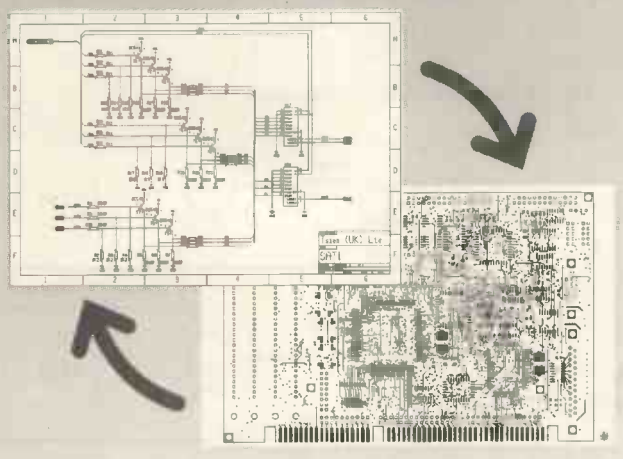
Finally an upgradeable PCB CAD system to suit any budget ...

BoardCapture

BoardCapture - Schematic Capture

- Direct netlist link to BoardMaker2
- Forward annotation with part values
- Full undo/redo facility (50 operations)
- Single-sheet, multi-paged and hierarchical designs
- Smooth scrolling
- Intelligent wires (automatic junctions)
- Dynamic connectivity information
- Automatic on-line annotation
- Integrated on-the-fly library editor
- Context sensitive editing
- Extensive component-based power control
- Back annotation from BoardMaker2

£395



BoardMaker

BoardMaker1 - Entry level

- PCB and schematic drafting
- Easy and intuitive to use
- Surface mount support
- 90, 45 and curved track corners
- Ground plane fill
- Copper highlight and clearance checking

£95

BoardMaker2 - Advanced level

- All the features of BoardMaker1 plus
- Full netlist support - OrCad, Schema, Tango, CadStar
- Full Design Rule Checking - mechanical & electrical
- Top down modification from the schematic
- Component renumber with back annotation
- Report generator - Database ASCII, BOM
- Thermal power plane support with full DRC

£395

BoardRouter

BoardRouter - Gridless autorouter

- Simultaneous multi-layer routing
- SMD and analogue support
- Full interrupt, resume, pan and zoom while routing

£200

Output drivers - Included as standard

- Printers - 9 & 24 pin Dot matrix, HPLaserjet and PostScript
- Penplotters - HP, Graphtec, Roland & Houston
- Photoplotters - All Gerber 3X00 and 4X00
- Excellon NC Drill / Annotated drill drawings (BM2)

Contact Tsien for further information on
Tel 01354 695959
Fax 01354 695957

tsien

Tsien (UK) Ltd Aylesby House Wenny Road Chatteris Cambridge PE16 6UT

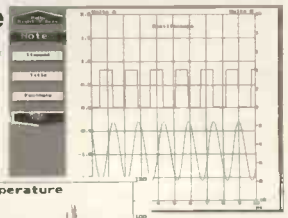
All trademarks acknowledged

AWV7:10-30

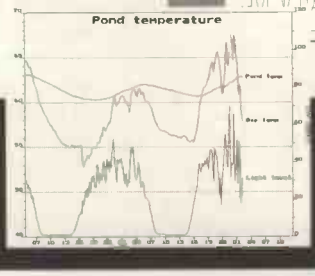
CIRCLE NO. 130 ON REPLY CARD

Join the 'Virtual Instrument' Revolution

PicoScope
'Virtual instrument' software



Pico's Virtual Instrumentation enable you to use your computer as a variety of useful test and measurement instruments or as an advanced data logger.



Hardware and software are supplied together as a package - no more worries about incompatibility or complex set-up procedures. Unlike traditional 'plug in' data acquisition cards, they simply plug into the PC's parallel or serial port, making them ideal for use with portable PC's.
Call for your Guide on 'Virtual Instrumentation'.

PicoLog
Advanced data logging software.

PICO TECHNOLOGY

NEW *SLA-16* Logic Analyser

Pocket sized 16 Channel Logic Analyser

- Connects to PC serial port
- High Speed Sampling - up to 50MHz
- Internal & external clock modes
- 8K Trace Buffer

SLA-16 with software, power supply and cables **£219**

NEW *ADC-100* Virtual Instrument

Dual Channel 12 bit resolution

- **Digital Storage Scope**
- **Spectrum Analyser**
- **Frequency Meter**
- **Chart Recorder**
- **Data Logger**
- **Voltmeter**

The ADC-100 offers both a high sampling rate (100kHz) and a high resolution. It is ideal as a general purpose test instrument either in the lab or in the field. Flexible input ranges (±200mV to ±20V) allows the unit to connect directly to a wide variety of signals.

ADC-10 Gives your computer a single channel of analog input. Prices from £ 49.

ADC-100 with PicoScope **£199**
with PicoScope & PicoLog **£209**

VISA

Pico Technology Ltd. Broadway House, 149-151 St Neots Rd, Hardwick, Cambridge. CB3 7QJ UK.
Tel: 01954 - 211716 Fax: 01954 - 211880

Access

Phone or FAX for sales, ordering information, data sheets, technical support. All prices exclusive of VAT. Carriage Overseas £9

CIRCLE NO. 131 ON REPLY CARD

'OFF-AIR' FREQUENCY STANDARD

Still Only
£195+VAT
carriage extra

- ★ Provides 10MHz, 5MHz & 1MHz
- ★ Use it for calibrating equipment that relies on quartz crystals, TCXOs, VXCOs, oven crystals
- ★ Phase locks to DROITWICH (rubidium controlled and traceable to NPL)
- ★ For ADDED VALUE also phase locks to ALLOUIS (cesium controlled and traceable to OP — French eq to NPL)
- ★ British designed and British manufactured
- ★ Options available include enhanced receiver, sine wave outputs and 13MHz output for GSM. Prices on application.

Output frequencies – 10MHz, 5MHz, 1MHz
Short term stability – better than $1x10^{-8}$ (1 sec)
Typical – $4x10^{-9}$ (1 sec)
Long term – tends to $2x10^{-12}$ (1000 sec)

SUPERB DUAL TRACE SCOPES, TELEQUIPMENT D61A, 10mV SENSITIVITY, 10uS-500mS/DIV (& x5), X-Y INPUTS, Z-MOD, INT/EXT/TV TRIGS, ETC. FROM £125

MARCONI TF2333 MF TRANS OSC/LEVEL METER	£75	T74 (VHF BC221) HET FREQ METER	£45
AMPROBE LT8100 2 RANGE TEMP RECORDER	£75	LEVELL TM6B MICRO V-METER 450MHz	£95
AMPROBE LAV3X AC V-METER RECORDERS	£75	FARNELL TSV70 Mk2 0-35V 10A, 0-70V 5A	£295
12"x20Ux31" DEEP INSTRUMENT RACKS	£99	H.P. 8445B PRE-SELECTOR 10MHz-18GHz	£395
JANKE & KUNKEL HI-SPEED MINI MIXER	£20	MARCONI TF2905/8 SINE/SQ/PULSE/BAR GEN	POA
COMMODORE PETS, PRINTERS, D/DRIVES, ETC	from £10 ea	HP 5340A 10Hz – 18GHz FREQUENCY COUNTER	£895
FLUKE 760A MULTIMETER CALIBRATOR	£249	HRO-MX RECEIVERS, COILS, PSU's, SPEAKERS	from £35
BRADLEY 171B MULTIMETER CALIBRATOR	£249	TIME 2004 DC VOLTAGE STANDARD 0.005%	£750
BRADLEY 191 DISTRIBUTION UNIT	£149	TIME 404S PRECISION mV SOURCE 0-1V 20mA	£95
HONEYWELL COLOUR GRAPHIC RECORDER	£295	TIME 2003N DCV POT/CAL 0-10V, NULL. ETC	£225
PLESSEY TCT10 SIG GEN/ANAL 50-300 BDS	£95	HP 3701A/3702B TX GENERATOR & BB RX	POA
PRECISION STD CELL MUIRHEAD K231A TEMP CONT	£195	19" x 60 VERO INSTRUMENT CASES BRAND NEW	£25
QUAD 303 STEREO POWER AMPS	£95	AVO VALVE TESTERS MK2, MK4 & CT160	from £49
DRAKE MN2700 MATCHING N/WORK & PS7 PSU	£195 ea	"GIBSON GIRL" EMERGENCY RADIO SET 500KCS	£65
H.P. 8505A VECTOR V/METER 1GHz	£395	ELECTRONIC VISUALS EV4020A NTSC V/SCOPE	£395
TELEQUIPMENT D83 50MHz 2 TRACE DEL T/B	£249	FERROGRAPH RTS2 TEST SET/AUX TEST UNIT	£295
GOULD OS1100-SI 30MHz DUAL TRACE	£149	PHILIPS PM5134 FUNCTION GEN 1MHz – 20MHz	£1495
KIKUSUI COS6100M 100MHz 5 TRACE DEL T/B	£495	PHILIPS PM5716 PULSE GENERATOR 1Hz-50MHz	£595
TEKTRONIX 545 PLUG-INS, VARIOUS	£10 to £15	BRADLEY 144 DC MULTIPLIER UNIT	£149
SCOPEX 4S6 6MHz SINGLE TRACE	£95	'XT' 'AT' & COMPAQ COMPUTERS	from £35
SCOPEX 4D10BL S. 10MHz WITH EXTENDED LF T/B	£149	LEVELL TM3B MICRO V-METER 3MHz	£85
LEADER LBO-9C ALIGNMENT SCOPE	£195	LING DYN VIB GEN 406 & PA300 PWR OSC	£995
IWATSU SS5116 DUAL TRACE 10MHz	£175	UDI2026 SONAR SCANNER. SURFACE UNIT	£975
TELEQUIPMENT D1011 10MHz DUAL TRACE	£165	CITOH CX6000 6-PEN A4 PLOTTER. CENT/RS232	£135
TELEQUIPMENT D67A 25MHz. ZT. DEL T/B	£215	GOULD 2400 4-PEN CHART RECORDER	£149
HITACHI VC 6015 10MHz DIGITAL STORAGE	£195	MARCONI TF2300 FM/AM MODULATION METER	£149
HP1340A X-Y DISPLAYS	£99	McKENZIE 7DAY TEMP/HUMIDITY RECORDER	£95
MARCONI TF2212 X-Y DISPLAY	£59	FEEDBACK SS0603 1MHz SINE/SQ OSC	£125

LIST AVAILABLE BUT 1000's OF UNLISTED BARGAINS FOR CALLERS. ALL PRICES EXC. OF P&P AND VAT
QUALITY ELECTRONIC EQUIPMENT ALWAYS WANTED

Access **HALCYON ELECTRONICS** VISA
423, KINGSTON ROAD, WIMBLEDON CHASE, LONDON SW20 8JR
SHOP HOURS 9-5.30 MON-SAT. TEL 081-542 6383. FAX 081-542 0340

CIRCLE NO. 132 ON REPLY CARD

FANTASTIC SAVINGS ON METERS AND MORE !!!

ALL PRICES INCLUDE VAT

METEX 4½ DIGIT DMM M4630 ■ 30 Range 4½ Digit Display 17mm ■ 0.05% Accuracy. Features: ■ 5 range capacitance test ■ 5 ohms ranges to 20M ■ Transistor and Diode Test ■ Continuity LED and buzzer ■ Data hold switch ■ 5-ranges AC/DC Volts ■ AC/DC current to 20 Amps ■ With leads, battery, instructions and hard case **£49.95**

TL34 ■ 33 Range ■ 3½ digit 24mm Large Display Features: ■ 5 Capacitance ranges ■ 6 - resistance ranges to 20M ohm ■ Diode and transistor test ■ 5 AC/DC volts ranges Basic 0.5% accuracy. ■ 5 ranges AC/DC current to 20 Amps ■ With leads, battery and instructions. **£27.95**

MX190 ■ 19 Range 3½ Digit Features: ■ AC/DC Volts (0.7%) ■ 0-1D ADC current ■ 0/2k/2MEG ohmresistance ■ Diode test ■ Signal injector function ■ With leads, battery and instructions **£13.95**

TEST METERS

Satellite Finder ■ Easy to use kit **£29.95**
Professional Satellite F/S meter **£89.95**
LCR Meter ■ 3½Digit ■ 7 Cap ■ 6 inductance ■ 7 resistance ranges **£67.95**
Capacitance Meter ■ 3½ Digit ■ 9 ranges ■ 18mm LCD display **£62.95**
Digital Lux Meter ■ 3 ranges ■ 3½ digit LCD ■ Data hold output terminal **£62.95**
Sound Level Meter ■ 40 to 120 db ■ Two ranges **£46.95**
Analogue Clamp Meter ■ 0/300 amps ■ AC 5 ranges ■ 0/750 VAC 0/75v DC ■ 0/200 K OHM **£32.95**
Digital Clamp Meter ■ 3½Digit ■ 11 ranges Incl temperature ■ Data hold etc. **£56.95**
AC/DC Current Clamp ■ 0/2000 amps AC/DC two ranges for use with Dmm's **£51.95**
Temperature Measurement ■ Dual input 3½ Digit °c/°f with thermocouple (XJ) **£41.95**

BENCH INSTRUMENTS

Digitol LED Capacitance autorange bench meter 0.1% **£93.00**
LCR bridge **£126.00**
7 Digit frequency counter 10HZ to 200MHZ **£87.00**

POWER SUPPLIES

†single meter *twin meter
0/24v dc 0/3amps **†£74.00**
0/24v dc 0/5amps **†£88.00**
0/30v dc 0/3 amps ***£140.00**
Twin version ***£260.00**
5-15v dc 0/4 amps **†£52.95**
0/30v DC 0/2½ Amps digital display **£99.95**

SIGNAL SOURCES 220/240v AC
6 Range RF Gen 100 KHZ to 150 MHZ (350MHZ Harmonics) **£122.00**
5- range Audio Gen 10HZ to 1 MHZ Sine/square **£119.00**
0.5HZ to 500KHZ Function Gen Sine/Sq/Triang **£124.00**

Full details send for instruments info pack (SAE 36p UK) Ref: TG

ALL PRICES INCLUDE VAT
OPEN 6 DAYS A WEEK

HENRY'S AUDIO ELECTRONICS
(Reg. Prop. Cubegate Ltd)
404 Edgware Rd, London W2 1ED
Tel: 071-724 3564/071-258 1831
Fax: 071-724 0322
Discounts for quantity and education

Access VISA

CIRCLE NO. 133 ON REPLY CARD

BOOKS TO BUY

Programmable Logic Handbook
Geoff Bostock
Logic circuit designers are increasingly turning to programmable logic devices as a means of solving problems. This book, for the established electronics engineer, student and technician, is a thorough introduction to programmable logic. Geoff Bostock will take you to a level where you, as a designer, can take full advantage of the growing product range of ASICs and other self-programmable arrays used in computer and control systems. Paperback 256 pages.
Price £19.95 ***0 7506 0808 0***

Understand Electrical and Electronic Maths
Owen Bishop
People who find maths difficult often have, as a result, difficulty in grasping electrical and electronics theory. This book has been written to help such students to understand the mathematical principles underlying their subject so that they can go on with confidence to tackle problems in practical circuits. Paperback 256 pages.
Price £14.95 ***0 7506 0924 9***

CIRCUIT MANUALS
Ray Marston
A series of books dealing with their subjects in an easy-to-read and non-mathematical manner, presenting the reader with many practical applications and circuits. They are specifically written, for the design engineer, technician and the experimenter, as well as the electronics student and amateur. All the titles are written by Ray Marston, a freelance electronics design engineer and international writer.

Op-amp Circuits Manual
Paperback 224 pages
Price £13.95 ***0 434 912077***

Audio IC Circuits Manual
Paperback 168 pages
Price £13.95 ***0 434 912107***

CMOS Circuits Manual
Paperback 192 pages
Price £13.95 ***0 434 912123***

Electronic Alarm Circuits Manual
Paperback 144 pages
Price £13.95 ***0 7506 00640***

Timer/Generator Circuits Manual
Paperback 224 pages
Price £13.95 0 434 912913

Diode, Transistor and FET Circuits Manual
Paperback 240 pages
Price £13.95 ***0 7506 0228 7***

Instrumentation and Test Gear Circuits Manual
Ray Marston
Modern instrumentation and test gear circuits of value to the industrial, commercial, or amateur electronic engineer or designer make up this book. Almost 500 outstandingly useful and carefully selected practical circuits are in here. This is one book you must have if you need access to practical working circuits ranging from simple attenuators and bridges to complex digital panel meters, waveform generators, and scope trace doublers. Paperback 400 pages.
Price £16.95 ***0 7506 0758 0***

Logic Designers Handbook
Andrew Parr
Easy to read, but none the less thorough, this book on digital circuits is for use by students and engineers and provides an accessible source of data on devices in the TTL and CMOS families. It's a 'Designers Handbook' that will live on the designer's bench rather than on the bookshelf. The basic theory is explained and then supported with specific practical examples. Paperback 488 pages.
Price £25.00 ***0 7506 0535 9***

Digital Audio and Compact Disc Technology
Luc Baert, Luc Theunissen & Guido Vergult
Essential reading for audio engineers, students and hi-fi enthusiasts. A clear and easy-to-follow introduction and includes a technical description of DAT (digital audio tape). Contents includes principles of digital signal processing, sampling, quantization, A/D conversion systems, codes for digital magnetic recording, principles of error correction, the compact disc, CD encoding, opto-electronics and the optical block, servo circuits in CD players, signal processing, digital audio recording systems, PCM, Video 8, R-DAT and S-DAT. Paperback 240 pages.
Price £16.95 ***0 7506 0614 2***

NEWNES POCKET BOOKS
A series of handy, inexpensive, pocket sized books to be kept by your side and used every day. Their size makes them an ideal 'travelling' companion as well.

Newnes Electronics Engineer's Pocket Book
Keith Brindley
Hardback 319 pages
Price £12.95 ***0 7506 0937 0***

Newnes Electronics Assembly Pocket Book
Keith Brindley
Hardback 304 pages
Price £10.95 ***0 7506 0222 8***

Newnes Television and Video Engineer's Pocket Book
Eugene Trundle
Hardback 384 pages
Price £12.95 ***0 7506 0677 0***

Newnes Circuit Calculations Pocket Book
T Davies
Hardback 300 pages
Price £10.95 ***0 7506 0195 7***

Newnes Data Communications Pocket Book
Michael Tooley
Hardback 192 pages
Price £12.95 ***0 7506 0427 1***

Newnes Telecommunications Pocket Book
JE Varrall & EA Edis
Hardback 400 pages
Price £12.95 ***0 7506 0307 0***

Newnes Z80 Pocket Book
Chris Roberts
Hardback 185 pages
Price £12.95 ***0 7506 0308 9***

Newnes 68000 Pocket Book
Mike Tooley
Hardback 257 pages
Price £12.95 ***0 7506 0309 7***

Newnes Electrical Pocket Book
21st edition
E A Parr
Paperback 526 pages
£12.95 ***0 7506 05138***

Newnes Electric Circuits Pocket Book Linear IC
Ray Marston
Hardback 336 pages
Price £12.95 ***0 7506 0132 9***

Newnes Guide to Satellite TV
D J Stephenson
A practical guide, without excessive theory of mathematics, to the installation and servicing of satellite TV receiving equipment for those professionally employed in the aerial rigging/TV trades. Hardback 256 pages.
Price £17.95 ***0 7506 0215 5***

Newnes Practical RF Handbook
Ian Hickman
Pressure on the RF spectrum has never been greater and it's people with knowledge and skills of RF design who are now in demand in the electronics industry to design, produce, maintain and use equipment capable of working in this crowded environment. This practical introduction to modern RF circuit design will equip you with the necessary RF knowledge and skills to enable you to compete effectively in the industry. Paperback 320 pages.
Price £16.95 ***0 7506 0871 4***

Troubleshooting Analog Circuits
R A Pease
Bob Pease is one of the legends of analog design. Over the years, he's developed techniques and methods to expedite the often-difficult tasks of debugging and

troubleshooting analog circuits. Now, Bob has compiled his 'battle-tested' methods in the pages of this book. Based on his immensely popular series in EDN Magazine, the book contains a wealth of new material and advice for Digital/Analog electronics engineers on using simple equipment to troubleshoot. Paperback 217 pages.
Price £14.95 ***0 7506 16326***

PC-Based Instrumentation and Control
M Tooley
Do you need information to enable you to select the necessary hardware and software to implement a wide range of practical PC-based instrumentation and control systems? Then this book is for you. Paperback 320 pages.
Price £14.95 ***0 7506 1631 8***

Electronic Circuits Handbook
M Tooley
Provides you with a unique collection of practical working circuits together with supporting information so that circuits can be produced in the shortest possible time and without recourse to theoretical texts. Paperback 345 pages.
Price £24.95 ***0 7506 0750 5***

Communication Services via Satellite
G E Lewis
DBS is already with us, and will create a series of new technical problems for engineers/technicians in television and communication services. This book gives you the solutions to these problems by: explaining how the system functions; describing several actual systems and giving several analyses and design rules. You can't afford to be without this invaluable technology update if you're a systems design engineer, service engineer or technician. Paperback 400 pages.
Price £25.00 ***0 7506 0437 9***

Digital Logic Design
Brian Holdsworth
As one of the most successful and well established electronics textbooks on digital logic design, this book reflects recent developments in the digital fields. The book also covers new functional logic symbols and logic design using MSI and programmable logic arrays. Paperback 448 pages.
Price £19. 50 ***0 7506 0501 4***

The Circuit Designers Companion
T Wiliams
This compendium of practical wisdom concerning the real-world aspects of electronic circuit design is invaluable for linear and digital designers alike. Hardback 320 pages.
Price £25 00 ***0 7506 1142 1***

Credit card orders accepted by phone
081 652 3614

Return to: Lorraine Spindler, Room L333, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS

Please supply the following titles:

Qty	Title	ISBN	Price
	Programmable Logic Handbook	07506 0808 0	19.95
	Understanding Electrical & Elec Maths	07506 0924 9	14.95
	Op-amp Circuits Manual	0434 912077	13.95
	Audio IC Circuits Manual	0434 912107	13.95
	CMOS Circuit Manual	0434 912123	13.95
	Electronic Alarm Circuits Manual	07506 0064 0	13.95
	Power Control Circuits Manual	07506 06908	13.95
	Timer/Generator Circuits Manual	0434 91291 3	13.95
	Diode, Transistor & FET Circuits Man	07506 0228 7	13.95
	Instrumentation & Test Gear Circuits Man	07506 0758 0	16.95
	Logic Designers Handbook	07506 0535 9	25.00
	Digital Audio and Compact Disc	07506 0614 2	16.95
	Newnes Elec Engineers Pkt Bk	0 7506 0937 0	12.95
	Newnes Elec Assemby Pk Bk	07506 0222 8	10.95
	Newnes TV and Video Eng Pkt Bk	07506 0677 0	12.95
	Newnes Circuit Calculations Pkt Bk	07506 0427 1	10.95
	Newnes Data Communications Pkt Bk	07506 0308 9	12.95
	Newnes Telecommunications Pkt Bk	07506 0307 0	12.95
	Newnes Z80 Pkt Bk	07506 0308 9	12.95
	Newnes 68000 Pkt Bk	07506 0309 7	12.95
	Newnes Electrical Pk Bk	07506 05138	12.95
	Newnes Electric Circuits Pocket Bk	07506 0132 9	12.95
	Newnes Guide to Satelite TV	07506 0215 5	17.95
	Newnes Practical RF Handbook	07506 0871 4	16.95
	Troubleshooting Analog Circuits	07506 16326	14.95
	PC-Based Instrumentation and Control	07506 1631 8	14.95
	Electronic Circuits Handbook	07506 0750 5	24.95
	Communication Services via Satellite	07506 0437 9	25.00
	Digital Logic Design	07506 05014	19.50

PLEASE ADD £2.50 FOR POSTAGE .....
Add VAT at local rate .....
NB ZERO RATE FOR UK & EIRE .....TOTAL

Business purchase: Please send me the books listed with an invoice. I will arrange for my company to pay the accompanying invoice within 30 days. I will attach my business card/letterhead and have signed the form below.
Guarantee: If you are not completely satisfied, books may be returned within 30 days in a resaleable condition for a full refund.

Remittance enclosed £ _____
Cheques should be made payable to **Reed Book Services Ltd.**
Please debit my credit card as follows:

Access/Master Barclay/Visa Amex Diners

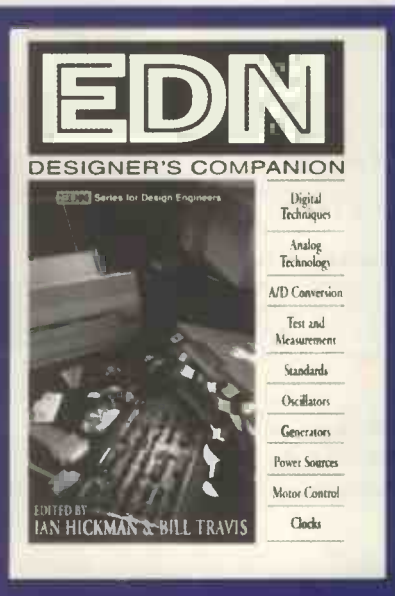
Credit Card No. _____ Exp date _____
NAME (Please print) _____
ORGANISATION _____
STREET _____
TOWN _____
COUNTY _____ POST CODE _____ COUNTRY _____
DATE _____ TELEPHONE NUMBER _____
SIGNATURE _____

T3000

VAT RATES
6% Belgium, 25% Denmark, 5.5% France, 7% Gemany, 4% Greece, 4% Italy, 3% Luxembourg, 6% Netherlands, 5% Portugal, 3% Spain. FOR COMPANIES REGISTERED FOR VAT, PLEASE SUPPLY YOUR REGISTRATION NUMBER BELOW (customers outside the EEC should leave this part blank)
VAT NO. _____
If in the UK please allow 28 days for delivery. All prices are correct at time of going to press but may be subject to change.
Please delete as appropriate. I do/do not wish to recieve further details about books, journals and information services.
Reed Business Publishing - Registered Office - Quadrant Hse The Quadrant Sutton Surrey SM2 5AS Registered in England 151537

Analogue design with a 5V supply

Op-amp selection can minimise the impact of single-supply design. Walt Jung and James Wong explain why careful choice is so important.*



EDN Designer's companion is available by postal application to room *L333 EW+WW, Quadrant House, The Quadrant, Sutton, Surrey, SM2 5AS.*
Cheques payable to Reed Book Services please. Credit card orders accepted by 'phone (081 652 3614).
254pp hardback ISBN0 7506 1721 7
Price £25.00+£2.50 postage.

Walt Jung and James Wong are with Analog Devices Inc. This article first appeared in EDN.

System designers are turning to single-supply power not just in digital applications but, increasingly, in analogue circuits. Some loss in performance can result. But using amplifiers expressly designed for the job can help minimise this loss, and among the performance specs that will be enhanced are supply-power and operating ranges, dynamic range, and input and output ranges. Better linear operation overall should result too.

Op-amps operating from +15V supplies generally accept an ample input common-mode (cm) range and provide a wide output range – both typically +10V or more. But single-supply systems often handle much smaller voltage ranges: 12V down to 5, 3, or even 1.5V. At these levels, most dual-supply op-amps simply cease to function. Those that will operate suffer performance degradation, and so choice of single-supply amplifiers is much more limited than that for dual-supply.

General-purpose amplifiers such as *741*s and *1558*s – and most fet-input amplifiers – can operate from supplies as low as ±5V, or 10V total. Precision-amplifier families such as the *OP-07* and *OP-27* do not work below 5V, though a few selected family types may be useful for some regions of this voltage spectrum. For example the *OP-97* proves useful down to ±2.25V (4.5V).

But, typically, only amplifiers specifically designed for single-supply or low-voltage operation can function without major performance compromises below 10V total.

Devices designed for ±15V operation typically require 2-5V of headroom, with respect to both supply rails and at both inputs and output. Even the more-flexible dual-supply amplifiers only come within 1V or so of the rails. Need for headroom in single-supply applications severely limits linear operation over wide signal swings. The limitations are most acute at lower supply voltages and, for this reason, single-supply amplifier input stages usually remain linear even when the common-mode voltage applied is right at the negative rail (ground) or even slightly below (≈ –200mV). Op-amp input stages that operate in this way include pnp bipolars, cmos or pmos types, and n-channel jfet types.

Common-mode stresses

Obviously, devices with the above various input stages will have differing input-bias currents, noise voltage and currents, and offset voltage and drift. Spec sheets will delineate these characteristics, but a subtle (and potentially important) characteristic for a given device is how it reacts to common-mode stresses.

Over-driving amplifiers below the negative rail (pnp inputs in particular) can cause a non-destructive output-phase reversal. Over-driving may not actually damage the device if the input-fault current is limited, but the circuitry around the amplifier can react violently. If the circuitry is a polarity-sensitive servo, for example, it may lock up or oscillate.

Few single-supply amplifiers have internal protection against over-drive. Fortunately, preventing it is easy: simply clamp the input voltage to no more than 300mV below the negative rail with a low-threshold Schottky diode.

Protection of cmos- and pmos-input stage amplifiers is more difficult because exceeding their supply rails can trigger a parasitic scr within the device – with possible destruction. As with any cmos device, possible transients should be kept in mind and data-sheet recommendations followed.

At the positive end of the input-cm range, some devices can operate to within 1V of the rail while others may need 1.5V of headroom.

Generally, over-driving an op-amp's common-mode inputs above the positive rail causes non-linearity (as opposed to phase reversal) and, again, cmos- or pmos-input devices should not be driven beyond the positive rail.

With the exception of rail-to-rail output-stage devices, most op-amps can swing only to within 1-2V of the positive rail and when these devices operate from supplies of 5V or less, output swing is greatly reduced. Even if the input's noise floor remains constant – it seldom does – the s/n ratio and dynamic range suffer for devices operating from low voltages.

Ultra-low quiescent current drain

A fundamental reason for using single-supply designs is to conserve power, so most single-supply op-amps draw low stand-by current. But very low current designs may involve fundamental trade-offs, and band width, slew rate, and input noise voltage are sometimes all sacrificed.

Stand-by current drain per amplifier channel can often make or break a device when a system's power consumption is critical. (There is no industry standard definition of low power. We suggest that devices drawing quiescent currents of ≤1mA/channel are low power, and those drawing <100µA/channel are micropower.)

Given a requirement for low-power designs, engineers face not just slower speeds but also band-width restrictions arising from higher circuit impedances.

Table. 1. Noise vs supply current trade-offs.

	Noise (nV/√Hz)	supply current/ channel
OP-295	51	160µA
AD820	12.5	750µA
AD822	12.5	750µA
OP-213	6	1.45mA

Table 2. Current vs band width trade-offs

	Current drain (µA/ch.)	Bandwidth	Slew rate (V/µs)
OP-295	160	75kHz	0.03
AD822	750	2MHz	3.5
324/358	500	1MHz	0.6

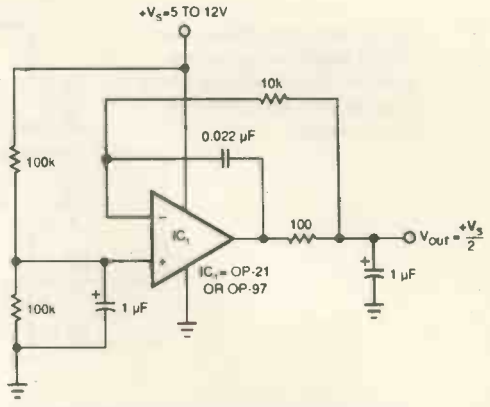


Fig. 1. False or "pseudo" grounds can be made any value desired. When dynamic currents are high, use this simple op-amp follower.

fully-buffered op-amp follower stages for the lowest wide-band dynamic impedance. When the dynamic current is low, a well by-passed noise-free divider is suitable for high-impedance loads. When high, a simple op-amp follower **(Fig. 1)** can do the job. In the circuit shown, a wide range of supplies can be used to produce a low-noise output of $V_{supply}/2$. Choice of IC_1 determines the circuit's standby current.

If a precise pseudo-ground voltage is needed, a reference IC that can source and sink current **(Fig. 2)** should be used.

Operating from a 5V supply, the suggested

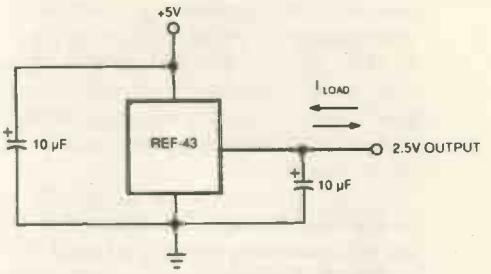


Fig. 2. Use a reference IC that can source and sink current if a precise pseudo-ground voltage is needed. This circuit can handle load currents both into and from the 2.5V source. Low-esr by-pass capacitors help keep the circuit's ac impedance low.

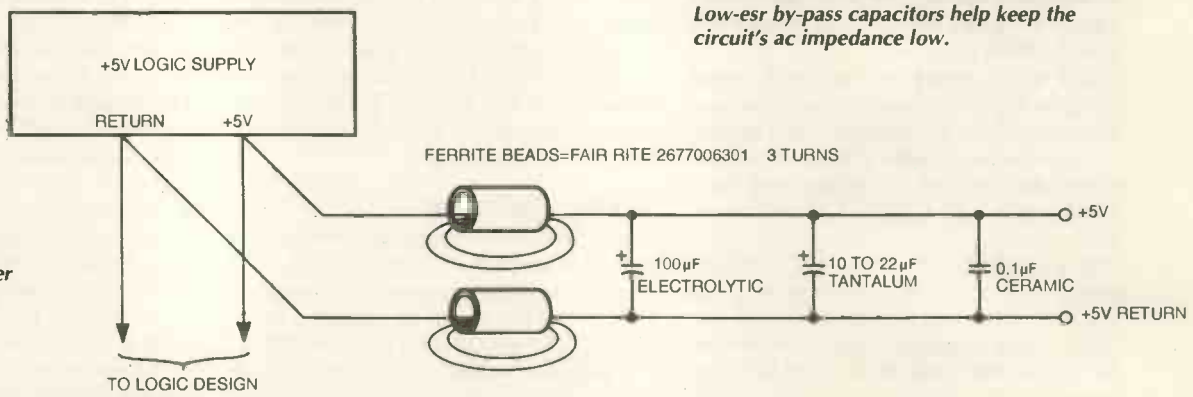


Fig. 3. Balanced IC filter suppresses glitch noise by 40dB or more.

Table 1 indicates trade-offs in noise versus supply current and Table 2, band width. The dual amplifiers in the Table 2 bracket the industry standard *324* and *358*, with their 500µA/channel current drain, 1MHz bandwidth, and 0.6V/µs slew rate. Greater speed also comes at the price of increased current.

Ground rules

Assigning ground is a task that can become important in single-supply, ac-coupled op-amp circuits. A false or pseudo ground can be anything required, the best choice depending on the individual application. But maximum amplifier flexibility helps make signal referencing less problematic, particularly if the design has substantial dynamic current into an elevated ground.

Possible choices for false ground range from simple ac-by-passed resistive dividers, to

circuit can handle load currents both into and from the 2.5V source. Low-esr (equivalent series resistance) by-pass capacitors help keep the circuit's ac impedance low.

Power supply noise

Power-supply noise, if not dealt with correctly, can shred even the best paper design. Low-power circuits tend to have poorer supply rejection, and the noise from commonly used 5V digital supplies is nearly worst-case. Simple power-line filters may not be adequate for high-performance analogue stages. A common analogue and digital supply may be attractive for size and cost reasons, but a common supply should be avoided if at all possible. Power taken from the middle of a logic layout contains huge amounts of high-frequency noise – 100mV or more. Worse yet, logic supplies are typically switching types,

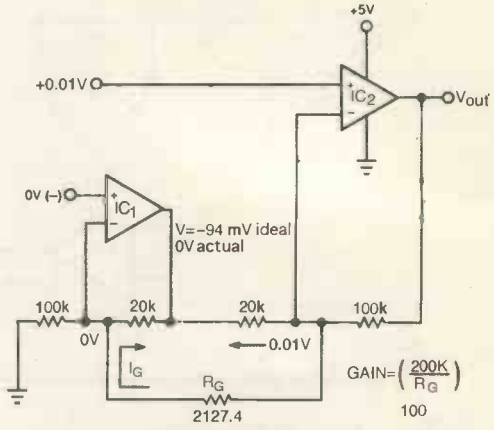


Fig. 4. Two op-amp instrumentation amplifier normally uses two supplies. Using a single supply constrains the design's common-mode range.

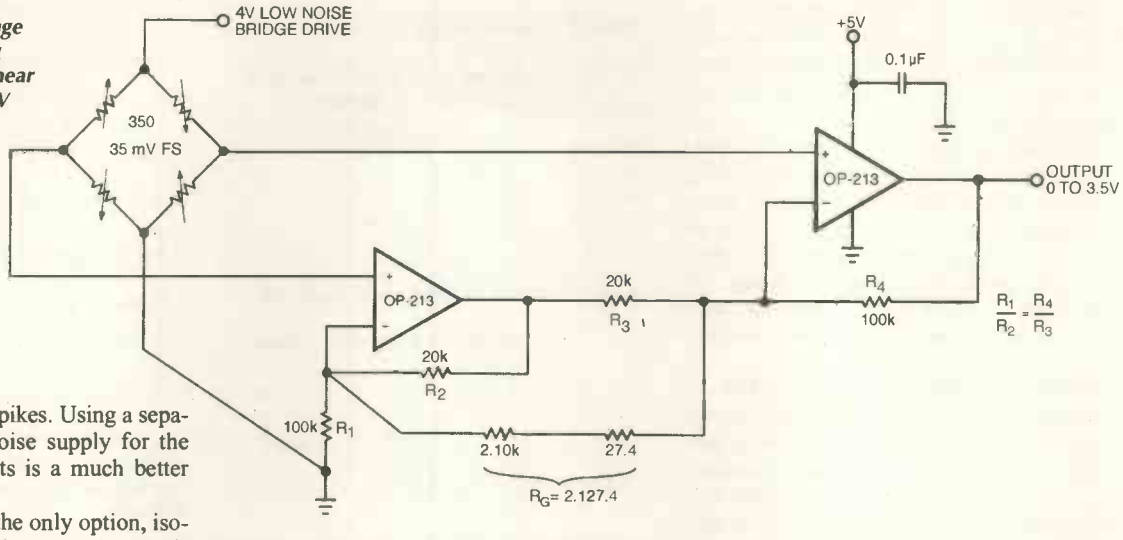


Fig. 5. Accurate strain gauge bridge amplifier operating from 5V and producing linear outputs to as low as 600µV from ground.

which have large output spikes. Using a separate, linear mode, low-noise supply for the sensitive analogue circuits is a much better idea whenever possible.

If a 5V logic supply is the only option, isolation and circuit partitioning, as well as optimised decoupling and filtering, can help greatly. Make sure the analogue power is tapped right at the supply terminals, not from the logic stages, so avoiding the voltage drops of the logic-supply runs and allowing maximum supply regulation.

By-pass capacitors alone are usually not adequate for filtering switch-mode glitches, so take additional steps such as a balanced IC filter **(Fig. 3)**. The filter comprises two high-frequency inductors – each made from a three-turn, toroidal ferrite bead – and a large, composite output capacitor. Capacitors should be low-esr switching types for best performance. As shown, the filter suppresses glitch noise by 40dB or more.

Even with a device that has a wide output swing, an application's configuration can limit that swing. Take, for example, a two op-amp instrumentation amplifier **(Fig. 4)**. It normally uses dual supplies, but in this case, has a single supply and a gain of approximately 100.

At first glance, the amp will faithfully amplify a 10mV differential input to 1V at V_{OUT} with a low common-mode voltage.

But a close examination proves otherwise. The output from amplifier IC_1 must be a negative 94mV to satisfy the loop's requirements and produce 1V at the output. Obviously, IC_1 cannot produce a negative output from a single supply. Indeed, if the circuit attempts such operation, IC_1 saturates, and V_{out} becomes non-linear.

As it turns out, this input-cm limitation is a function of the instrumentation amp's gain as well as the output swing of the op-amps within it. So, low negative-V_{sat} or rail-to-rail output-stage op-amps help improve common-mode handling. In Fig. 4 the worst-case minimum cm voltage is 0.4V (assuming a 5V output swing and each op-amp swinging to within 100µV of each rail). Op-amps that cannot swing to 0V will have a worse input cm-voltage minimum. The conclusion is that even though an op-amp might be designed for single-supply operation, a particular configuration could still constrain it.

Sensible application

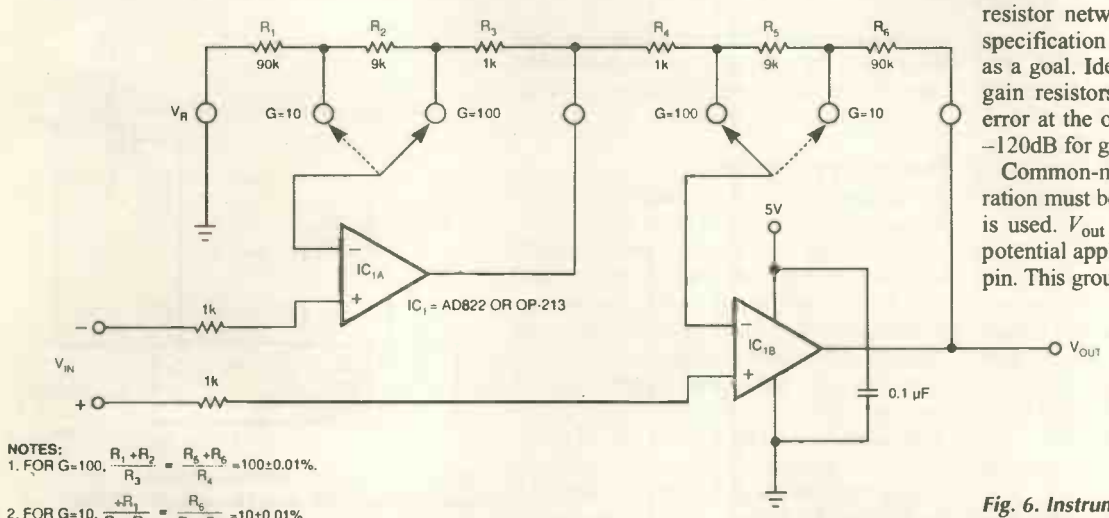
But despite its basic limitations, the topology can still be useful if it is carefully applied. For example, consider an accurate strain-gauge bridge amplifier circuit in which the bridge and amplifier are powered from 5V **(Fig. 5)**. The amplifier produces linear outputs to as low as 600µV from ground. In this case, the bridge itself supplies the 2V common-mode bias, keeping the op amps in the middle of their common-mode range. Driving the bridge with a low-noise 4V supply further minimises noise.

Design of an instrumentation amplifier that shrugs off switch resistance is also possible **(Fig. 6)**. Compared with the circuit in Fig. 4, this circuit's primary advantage is that it does not exhibit extreme common-mode limitations. Also, its topology switches divider taps for gain changes, so moderate switch resistances (10 to 100Ω) do not cause major errors. A circuit's gain can easily be set with jumpers or dpdt cmos switches. However, adding the same gain setting switches in series with R_G in Fig. 4 would produce serious errors.

In Fig. 6, amplifier IC_{1A} is a follower for signals at terminal $-V_{in}$. IC_{1B} is a follower for signals at $+V_{in}$, and an inverter for signals at its negative input. Linear subtraction of cm signals and amplification of differential signals provides the circuit with a precise gain that can be varied between 10 and 100.

Performance keys to this circuit are the resistor network and the amplifier. For best performance with premium amplifiers, the resistor network should have a ratio-match specification of 0.1% minimum, with 0.01% as a goal. Ideal amplifiers and 0.01%-match gain resistors will have the common-mode error at the output on the order of –100 and –120dB for gains of 10 and 100, respectively.

Common-mode limitations of the configuration must be observed when a single supply is used. V_{out} in the circuit is referred to the potential applied to the resistor network's V_R pin. This ground assignment implies that if the



NOTES:
1. FOR G=100, $\frac{R_1+R_2}{R_3} = \frac{R_5+R_6}{R_4} = 100 \pm 0.01\%$.
2. FOR G=10, $\frac{+R_1}{R_2+R_3} = \frac{R_6}{R_4+R_5} = 10 \pm 0.01\%$.
3. R_1 TO R_6 ARE PART OF THE OHMTEK (NIAGARA FALLS, NY) 1043.

Fig. 6. Instrumentation amplifier that shrugs off switch resistance, enabling gains to be switched.

circuit has to exhibit high linearity for even small V_{in} difference voltages, the op-amps should be able to swing close to ground.

Output-stage swing

Not all single-supply amplifier outputs can swing to the negative rail (ground). Some may swing to within a diode drop (0.6V); others may swing within a few tens of millivolts. Only a very few swing to less than 1mV from the negative rail.

To understand which op-amp functions best for output-swing-critical applications, calls for detailed knowledge of output stages.

Figure 7 shows a sampling of output-stage topologies used in single-supply op-amps. At best, the bipolar complementary emitter-follower stage is only active to within a diode drop of each rail. It may or may not use a Darlington for transistor Tr_1 – but usually has a single pnp for Tr_2 – and cannot swing to ground without outside help, such as the added resistor $R_{pulldown}$. This resistor allows output linearity to ground for source-type loads only, while also raising overall dissipation for sustained high-level outputs.

Amplifiers with this type of output stage can be useful for single-supply applications, but must be carefully applied for all trade-offs to be optimised.

The nmos bipolar emitter-follower common-source output stage **(Fig. 7b)** has, by nature, an asymmetrical voltage swing. However, it exhibits low saturation voltages to ground because of the nmos pull-down transistor N_1. Saturation voltage to the positive rail is about 1V (or more), and the advantage of the stage is that the nmos pull-down transistor can drive current-sink loads to within a few millivolts of ground – enhancing the linearity in many single-supply applications.

The cmos stage **(Fig. 7c)** is, by definition, fully complementary and offers a resistive connection to the supply rail for a high or low output, rail to rail. With appropriate low-R_{on} transistors for P_1 and N_1, saturation drops to either rail can be a millivolt or less at low currents. The stage is inherently class A so amplifier design must carefully control the static currents in P_1 and N_1 for low quiescent current. But for output currents of a few milliamps, this type of output stage is effective and quite versatile because of its rail-to-rail nature.

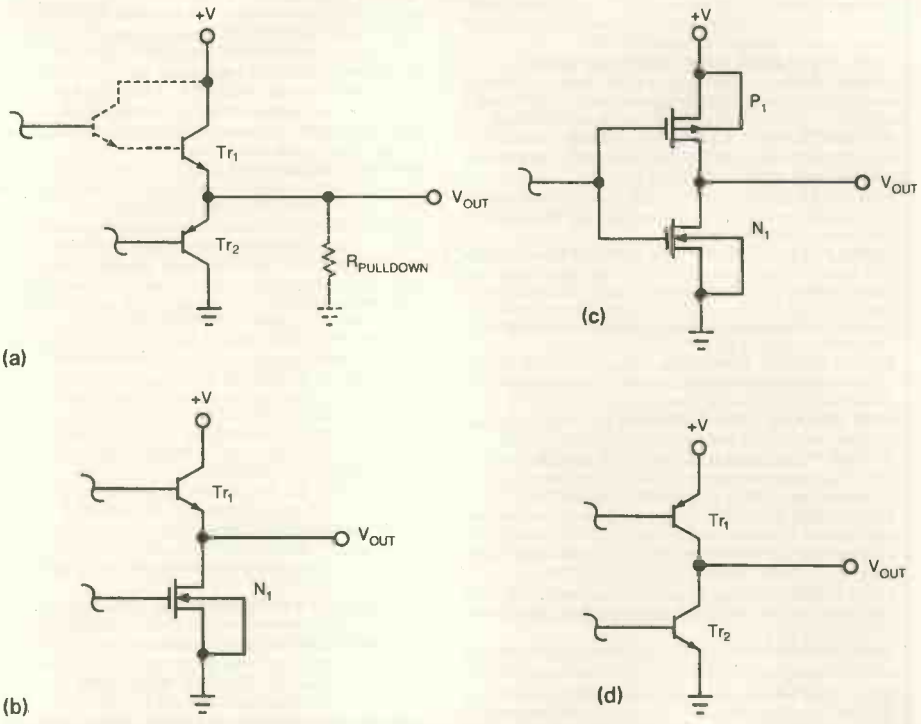


Fig. 7. Output-stage topologies used in single-supply op amps. The bipolar complementary emitter-follower stage (a) is active only to within a diode drop of each rail at best. The bipolar emitter-follower, nmos common-source output stage (b) has by nature, an asymmetrical voltage swing. The cmos stage (c) is, by definition, fully complementary. Complementary-bipolar common-emitter stage (d) is another rail-to-rail output stage.

The complementary-bipolar common-emitter stage **(Fig. 7d)** is another rail-to-rail output stage. Saturation-drops to the rails range from a few millivolts to hundreds of millivolts over current ranges up to 20mA. Like the cmos rail-to-rail output stage, this bipolar counterpart is both effective and versatile, but avoidance of punitive trade-offs in power is critical to design of the bipolar stage. ■

ELECTRONICS WORLD *SOFT INDEX*

A computerised index of *Electronics World+Wireless World* magazine is now available. It covers the five years 1990 to 1994 – volumes 96 to 100 – and contains over 1400 references to feature articles, circuit ideas and applications, with a synopsis for each. The software is easy to use and very quick. It runs on any IBM or compatible PC with 512K ram and a hard disk. Each disk is scanned before shipping with the current version of Dr Solomon's Anti-Virus Toolkit.

For the UK, the five year index is priced at £20. Please specify $5^1/_4$ or $3^1/_2$in format. This price includes UK postage and VAT. Add an extra £1 for overseas EC orders or £5 for non-EC overseas orders.

Photo copies from back issues of *EW+WW* are available at 50p per page plus VAT (in EC) and a flat postage charge of 50p UK, £1 rest of EC, and £2 rest of world. For enquiries about photo copies send an sae to Video Interface Products.

Please allow up to 28 days for delivery. Cheques should be made payable to **Video Interface Products**, not *EW&WW* or Reed Business Publishing.

Please post your request to **Video Interface Products Ltd, 1 Vineries Close, Cheltenham GL53 0NU, UK.**

A4 DTP MONITORS Brand new, 300 DPI. Complete with diagram but no interface details.(so you will have to work it out!) Bargain at just £12.99 each!!!!

OPD MONITORS 9" mono monitor, fully cased complete with raster board, switched mode psu etc. CGA/TTL input (15way D), IEC mains. £15.99 ref DEC23. Price including kit to convert to composite monitor for CCTV use etc is £21.99 ref DEC24

LOW COST LASER NIGHT SIGHT just £79!!! Cheaper version of our £245 Cyclops model, works ok in low light levels or in complete darkness with the built in Laser. ref 95/79 (please allow about 1 month delivery for these due to import difficulties)

PC CONTROLLED 4 CHANNEL TIMER Control (on/off times etc) up to 4 items (8A 240v each) with this kit. Complete with Software, relays, PCB etc. £25.99 Ref 95/26

LOW COST RADAR DETECTOR Built and tested pocket radar detector, ideal for picking up speed traps etc. Why pay £70 or more? ours is just £24.99 ref 95/25.

COMPLETE PC 300 WATT UPS SYSTEM Top of the range UPS system providing protection for your computer system and valuable software against mains power fluctuations and cuts. New and boxed, UK made Provides up to 5 mins running time in the event of complete power failure to allow you to run your system down correctly. SALE PRICE just £119.00.

RACAL MODEM BONANZA! 1 Racal MPS1223 1200/75 modem, telephone lead, mains lead, manual and comms software, the cheapest way onto the net! all this for just £13 ref DEC13.

HOW LOW ARE YOUR FLOPPIES? 3.5" (1.44) unbranded. We have sold 100,000+ so ok! Pack of 50 £24.99 ref DEC16

BRITISH TELECOMM MULTIMETERS SA9083 These are 'returns' so they may have faults but look ok. Complete with new leads and leather case. Price for two meters & 1 case is £10 ref DEC89.

5mw LASER POINTER. Supplied in kit form, complete with power adjuster, 1-5mw, and beam divergence adjuster. Runs on 2 AAA batteries. Produces thin red beam ideal for levels, gun sights, experiments etc. Cheapest in the UK! Just £39.95 ref DEC49

SHOP WOBBLERS! Small assemblies designed to take D size batteries and 'wobble' cardboard model signs about in shop windows! £3.99 Ref SEP4P2.

RADIO PAGERS Brand new, UK made pocket pagers clearance price is just £4.99 each 100x40x15mm packed with bits! Ref SEP5.

BULL TENS UNIT Fully built and tested TENS (Transcutaneous Electrical Nerve Stimulation) unit, complete with electrodes and full instructions. TENS is used for the relief of pain etc in up to 70% of sufferers. Drug free pain relief, safe and easy to use, can be used in conjunction with analgesics etc. £49 Ref TEN/1

STEREO MICROSCOPE 155X195MM, up to 600mm high, so items up to 10" will fit under lense. Rack and pinion focusing, 6 interchangeable rotating object lenses, interchangeable eye pieces, +scaled eyepiece for accurate measuring etc. Powerful low voltage illumination system with green filter and variable intensity, 100mm black/white + ground glass stage plate, 70mm swivel mirror, adjustabe eyepieces (both focus and width). Magnification range 4.6-100.8, field of view 39-2.4mm). Price is £299 for complete setup. Ref 95/300.

3D 36MM CAMERA SYSTEM Complete kit to convert a standard 35mm camera into a 3D version!, enable you to take 3D colour slides with your own camera! Kit contains a prism assembly for the front of your existing lense, a sample 3D slide, a 3D slide viewer and 2 different lense mounts 49mm and 52mm, (other sizes available from photo shops at about £3 ea) all you need is standard slide film. Price for the complete kit is £29.99 ref 95/30.

COMPUTER RS232 TERMINALS. (LIBERTY) Excellent quality modem units,(like wyse 50,s) 2xRS232, 20 function keys, 50 thro to 38,400 baud, menu driven port, screen, cursor, and keyboard setup menus (18 menu's). £29 REF NOV4.

OMRON TEMPERATURE CONTROLLERS (E5C2). Brand new controllers, adjustable from -50 deg C to +1,200 deg C using graduated dial, 2% accuracy, thermocouple input, long life relay output .3A 240v o/p contacts. Perfect for exactly controlling a temperature, Normal trade £50+, ours £15. Ref E5C2.

ELECTRIC MOTOR BONANZA! 110x60mm. Brand new precision, cap start (or spin to start), virtually silent and features a moving outer case that acts as a fly wheel. Because of their unusual design we think that 2 of these in a tube with some homemade fan blades could form the basis for a wind tunnel etc. Clearance price is just £4.99 FOR A PAIR! (note- these will have to be wired in series for 240v operation Ref NOV1.

MOTOR NO 2 BARGAIN 110x90mm. Similar to the above motor but more suitable for mounting vertically (ie turntable etc). Again you will have to wire 2 in series for 240v use. Bargain price is just £4.99 FOR A PAIR!! Ref NOV3.

OMRON ELECTRONIC INTERVAL TIMERS.

Minature adjustable timers, 4 pole c/o output 3A 240v,

HY1230S, 12vDC adjustable from 0-30 secs. £9.99
HY1210M, 12vDC adjustable from 0-10 mins. £9.99
HY1260M, 12vDC adjustable from 0-60 mins. £9.99
HY2460M, 24vAC adjustable from 0-60 mins. £5.99
HY241S, 24vAC adjustable from 0-1 secs. £5.99
HY2460S, 24vAC adjustable from 0-60 secs, £5.99
HY243H, 24vAC adjustable from 0-3 hours. £8.99
HY2401S, 240v adjustable from 0-1 secs. £9.99
HY2405S, 240v adjustable from 0-5 secs. £9.99
HY24060m, 240v adjustable from 0-60 mins. £12.99

PC PAL VGA TO TV CONVERTER Converts a colour TV into a basic VGA screen. Complete with built in psu, lead and s/ware. £49.95. Ideal for laptops or a cheap upgrade.

EMERGENCY LIGHTING UNIT Complete unit with 2 double bulb floodlights, built in charger and auto switch. Fully cased. 6v 8AH lead acid req'd. (secondhand) £4 ref MAG4P11.

GUIDED MISSILE WIRE. 4,200 metre reel of ultra thin 4 core insulated cable, 28lbs breaking strain, less than 1mm thick! Ideal alarms, intercoms, fishing, dolls house's etc. £14.99 ref MAG15P5

300v PANEL METER 70X60X50MM, AC, 90 degree scale. Good quality meter. £5.99 ref MAG 6P14. Ideal for monitoring mains etc.

ASTEC SWITCHED MODE PSU BM41012 Gives +5 @ 3.75A, +12@1.5A, -12@.4A. 230/110, cased, BM41012 £5.99 ref AUG6P3.

TORRODIAL TX 30-0-30 480VA, Perfect for Mosfet amplifiers etc. 120mm dia 55mm thick. £18.99 ref APR19.

AUTO SUNCHARGER 155x300mm solar panel with diode and 3 metre lead fitted with a cigar plug. 12v 2watt, £9.99 ea ref AUG10P3.

FLOPPY DISCS DSDD Top quality 5.25" discs, these have been written to once and are unused. Pack of 20 is £4 ref AUG4P1.

ECLATRON FLASH TUBE As used in police car flashing lights etc, full spec supplied, 60-100 flashes a min. £9.99 ref APR10P5.

24v AC 96WATT Cased power supply. New. £13.99 ref APR14.

MILITARY SPEC GEIGER COUNTERS Unused anstraight from Her majesty's forces. £50 ref MAG 50P3.

STETHOSCOPE Fully functioning stethoscope, ideal for listening to hearts, pipes, motors etc. £6 ref MAR6P6.

OUTDOOR SOLAR PATH LIGHT Captures sunlight during the day and automatically switches on a built in lamp at dusk. Complete with sealed lead acid battery etc.£19.99 ref MAR20P1.

ALARM VERSION Of above unit comes with built in alarm and pir to deter intruders. Good value at just £24.99 ref MAR25P4.

CARETAKER VOLUMETRIC Alarm, will cover the whole of the ground floor against forcred entry. Includes mains power supply and integral battery backup. Powerful internal sounder, will take external bell if req'd. Retail £150+, ours? £49.99 ref MAR50P1.

TELEPHONE CABLE White 6 core 100m reel complete with a pack of 100 clips. Ideal 'phone extns etc. £7.99 ref MAR8P3.

MICRODRIVE STRIPPER Small cased tape drives ideal for stripping, lots of useful goodies including a smart case, and lots of components. £2 each ref JUN2P3.

SOLAR POWER LAB SPECIAL You get TWO 6"x6" 6v 130mA solar cells, 4 LED's, wire, buzzer, switch plus 1 relay or motor. Superb value kit just £5.99 REF: MAG6P8

SOLID STATE RELAYS Will switch 25A mains. Input 3.5-26v DC 57x43x21mm with terminal screws £3.99 REF MAG4P10

300DPI A4 DTP MONITOR Brand new but shop soiled so hence bargain price! TTL/ECL inputs, 15" landscape, 1200x1664 pixel complete with circuit diag to help you interface with your projects. JUST £14.99. REF JUN15P2.

BUGGING TAPE RECORDER Small voice activated recorder, uses micro cassette complete with headphones. £28.99 ref MAR29P1.

ULTRAMINI BUG MIC 6mmx3.5mm made by AKG, 5-12v electret condenser. Cost £12 ea, Ours? just four for £9.99 REF MAG10P2.

RGB/CGA/EGA/TTL COLOUR MONITORS 12" in good condition. Back anodised metal case. £79 each REF JUN79

ANSWER PHONES Returns with 2 faults, we give you the bits for 1 fault, you have to find the other yourself. BT Response 200's £18 ea REF MAG18P1. PSU £5 ref MAG5P12.

SWITCHED MODE PSU ex equip, 60w +5v @5A, -5v@.5A, +12v@2A,-12v@.5A 120/220v cased 245x88x55mm IEC input socket £6.99 REF MAG7P1

PLUG IN PSU 9V 200mA DC £2.99 each REF MAG3P9

PLUG IN ACORN PSU 19v AC 14w , £2.99 REF MAG3P10

POWER SUPPLY fully cased with mains and o/p leads 17v DC 900mA output. Bargain price £5.99 ref MAG6P9

ACORN ARCHIMEDES PSU +5v @ 4.4A. on/off sw uncased, selectable mains input, 145x100x45mm £7 REF MAG7P2

GEIGER COUNTER KIT Low cost professional twin tube, complete with PCB and components. Now only £19 REF AUG19.

9v DC POWER SUPPLY Standard plug in type 150ma 9v DC with lead and DC power plug. price for two is £2.99 ref AUG3P4.

AA NICAD PACK encapsulated pack of 8 AA nicad batteries (tagged) ex equip, 55x32x32mm. £3 a pack. REF MAG3P11

13.8V 1.9A psu cased with leads. Just £9.99 REF MAG10P3

PPC MODEM CARDS. These are high spec plug in cards made for the Amstrad laptop computers. 2400 baud dial up unit complete with leads. Clearance price is £5 REF: MAG5P1

INFRA RED REMOTE CONTROLLERS Originally made for hi spec satellite equipment but perfect for all sorts of remote control projects. Our clearance price is just £2 REF: MAG2

200 WATT INVERTER Converts 10-15v DC into either 110v or 240v AC. Fully cased 115x36x156mm, complete with heavy duty power lead, cigar plug, AC outlet socket. Auto overload shutdown, auto short circuit shut down, auto input over voltage shutdown, auto input under voltage shut down (with audible alarm), auto temp control, unit shuts down if overheated and sounds audible alarm. Fused reversed polarity protected. output frequency within 2%, voltage within 10%. A extremely well built unit at an excellent price. Just £64.99 ref AUG65.

UNIVERSAL SPEED CONTROLLER KIT Designed by us for the C5 motor but ok for any 12v motor up to 30A. Complete with PCB etc. A heat sink may be required. £17.00 REF: MAG17

MAINSCABLE Precut black 2 core 2 metre lengths ideal for repairs, projects etc. 50 metres for £1.99 ref AUG2P7.

COMPUTER COMMUNICATIONS PACK Kit contains 100m of 6 core cable, 100 cable clips, 2 line drivers with RS232 interfaces and all connectors etc. Ideal low cost method of communicating between PC's over a long distance. Complete kit £8.99.

MINI CYCLOPS PIR 52x62x40mm runs on PP3 battery complete with shrill sounder. Cheap protection at only £5.99 ref MAR6P4.

ELECTRIC MOTOR KIT Comprehensive educational kit Includes all you need to build an electric motor. £9.99 ref MAR10P4.

VIDEO SENDER UNIT. Transmits both audio and video signals from either a video camera, video recorder, TV or Computer etc to any standard TV set in a 100' range! (tune TV to a spare channel) 12v DC op. Price is £15 REF: MAG15 12v psu is £5 extra REF: MAG5P2

***FM CORDLESS MICROPHONE** Small hand held unit with a 500' range! 2 transmit power levels. Reqs PP3 9v battery. Tuneable to any FM receiver. Price is £15 REF: MAG15P1

LOW COST WALKIE TALKIES Pair of battery operated units with a range of about 200'. Ideal for garden use or as an educational toy. Price is £8 a pair REF: MAG 8P1 2 x PP3 req'd.

***MINATURE RADIO TRANSCEIVERS** A pair of walkie talkies with a range of up to 2km in open country. Units measure 22x52x155mm. Including cases and earp'ces. 2xPP3 req'd. £30.00 pr. REF: MAG30

COMPOSITE VIDEO KIT. Converts composite video into separate H sync, V sync, and video. 12v DC. £8.00 REF: MAG8P2.

LQ3500 PRINTER ASSEMBLIES Made by Amstrad they are entire mechanical printer assemblies including printhead, stepper motors etc etc In fact everything bar the case and electronics, a good strippert £5 REF: MAG5P3 or 2 for £8 REF: MAG8P3

LED PACK of 100 standard red 5m leds £5 REF MAG5P4

UNIVERSAL PC POWER SUPPLY complete with flyleads, switch, fan etc. Two types available 150w at £15 REF:MAG15P2 (23x23x23mm) and 200w at £20 REF: MAG20P3 (23x23x23mm)

***FM TRANSMITTER** housed in a standard working 13A adapter!! the bug runs directly off the mains so lasts forever! why pay £700? or price is £26 REF: MAG26 Transmits to any FM radio.

***FM BUG KIT** New design with PCB embedded coil for extra stability. Works to any FM radio. 9v battery req'd. £5 REF: MAG5P5

***FM BUG BUILT AND TESTED** superior design to kit. Supplied to detective agencies. 9v battery req'd. £14 REF: MAG14

TALKING COIN BOX STRIPPER originally made to retail at £79 each, these units are designed to convert an ordinary phone into a payphone. The units have the locks missing and sometimes broken hinges. However they can be adapted for their original use or used for something else?? Price is just £3 REF: MAG3P1

TOP QUALITY SPEAKERS Made for HI FI televisions these are 10 watt 4R Jap made 4" round with large shielded magnets. Good quality. £2 each REF: MAG2P4 or 4 for £6 REF: MAG6P2

TWEETERS 2" diameter good quality tweeter 140R (ok with the above speaker) 2 for £2 REF: MAG2P5 or 4 for £3 REF: MAG3P4

AT KEYBOARDS Made by Apricot these quality keyboards need just a small mod to run on any AT, they work perfectly but you will have to put up with 1 or 2 foreign keycaps! Price £6 REF: MAG6P3

HEADPHONES Ex Virgin Atlantic. 8 pairs for £2 REF: MAG2P8

DOS PACKS Microsoft version 3.3 or higher complete with all manuals or price just £5 REF: MAG5P8 Worth it just for the very comprehensive manuall 5.25" only.

DOS PACK Microsoft version 5 Original software but no manuals hence only £5.99. 3.5" only.

PIR DETECTOR Made by famous UK alarm manufacturer these are hi spec, long range internal units. 12v operation. Slight marks on case and unboxed (although brand new) £8 REF: MAG8P5

MOBILE CAR PHONE £5.99 Well almost! complete in car phone excluding the box of electronics normally hidden under seat. Can be made to illuminate with 12v also has built in light sensor so display only illuminates when dark. Totally convincing! REF: MAG6P6

ALARM BEACONS Zenon strobe made to mount on an external bell box but could be used for caravans etc. 12v operation. Just connect up and it flashes regularly) £5 REF: MAG5P11

6"X12" AMORPHOUS SOLAR PANEL 12v 155x310mm 130mA. Bargain price just £5.99 ea REF MAG6P12.

FIBRE OPTIC CABLE BUMPER PACK 10 metres for £4.99 ref MAG5P13 ideal for experimenters! 30 m for £12.99 ref MAG13P1

HEATSINKS (finned) TO220, designed to mount vertically on a pcb 50x40x25mm you can have a pack of 4 for £1 ref JUN1P11.

INFRARED LASER NIGHT SCOPES

Image Intensifier complete with hand grip attachment with built in adjustable laser lamp for zero light conditions. Supplied with Pentax 42mm camera mount and normal eye piece. 1.6kg, uses 1xPP3, 3xAA's Please allow us about 1 month for delivery on this product due to import problems ! £245+Vat

NEW HIGH POWER LASERS

15mW, Helium neon, 3 switchable wavelengths .63um, 1.15um, 3.39um (2 of them are infrared) 500:1 polarizer built in so good for holography. Supplied complete with mains power supply. 790x65mm. Use with EXTREME CAUTION AND QUALIFIED GUIDANCE. £349+Vat.

WE BUY SURPLUS STOCK FOR CASH

1995 100 PAGE CATALOGUE NOW AVAILABLE, 45P STAMP OR FREE WITH ORDER.

3FT X 1FT 10WATT SOLAR PANELS
14.5v/700mA
£44.95

(PLUS £2.00 SPECIAL PACKAGING CHARGE)

TOP QUALITY AMORPHOUS SILICON CELLS HAVE ALMOST A TIMELESS LIFESPAN WITH AN INFINITE NUMBER OF POSSIBLE APPLICATIONS, SOME OF WHICH MAY BE CAR BATTERY CHARGING, FOR USE ON BOATS OR CARAVANS, OR ANYWHERE A PORTABLE 12V SUPPLY IS REQUIRED.

PORTABLE RADIATION DETECTOR

WITH NEW COMPUTER INTERFACE.

£59.00

A Hand held personal Gamma and X Ray detector. This unit contains two Geiger Tubes, has a 4 digit LCD display with a Piezo speaker, giving an audio visual indication. The unit detects high energy electromagnetic quanta with an energy from 30K eV to over 1.2M eV and a measuring range of 5-9999 UR/h or 10-99990 Nr/h. Supplied complete with handbook. Ref. NOV18.

*SOME OF OUR PRODUCTS MAY BE UNLICENSABLE IN THE UK

BULL ELECTRICAL

250 PORTLAND ROAD HOVE SUSSEX
BN3 5QT (ESTABLISHED 50 YEARS)

MAIL ORDER TERMS: CASH PO OR CHEQUE WITH ORDER PLUS £3.00 POST PLUS VAT.

PLEASE ALLOW 7 - 10 DAYS FOR DELIVERY
TELEPHONE ORDERS WELCOME

TEL: 01273 203500
FAX: 01273 323077

VISA

CIRCLE NO. 134 ON REPLY CARD

NEW PRODUCTS CLASSIFIED

Please quote *"Electronics World + Wireless World"* when seeking further information

ACTIVE

Asics

Mixed-signal, 50V asics. *AMS* can now supply mixed-signal asics that take a 50V supply voltage and offer the option of a second polysilicon layer. Integrating bipolar transistors in a cmos device makes for lower power consumption and fast switching. Since high voltage is needed to drive fast power fets, this process allows a low-cost cmos driver to control fets handling up to several hundred amps. It also enables the construction of floating polysilicon-polysilicon capacitors, removing voltage-dependence problems and parasitics. Austria Mikro Systeme International. Tel., 01276 23399; fax, 01276 29353.

A-to-D and D-to-A converters

Modulator. Crystal Semiconductor has introduced the *CS5321*, a delta-sigma modulator meant for use with the *CS5322* filter to form a 24-bit analogue-to-digital converter. *CS5321* implements a fourth-order, 256 times oversampled modulator to give 123dB dynamic range at a thd of 118dB, while consuming only 70mW for both chips. Use of the switched-capacitor technique reduces the effects of clock jitter without the use of plls and vcos. Sequoia Technology Ltd. Tel., 01734 258000; fax, 01734 258020.

Measuring amplifier. To overcome the limitations of purely analogue measurements from mechanical transducers, such as inferior accuracy, lack of set-up storage and size, HBM introduces the *MGC Measuring Amplifier System*, which uses gate-array techniques to produce a new analogue-to-digital converter and flexible dsp to do the signal conditioning. Analogue signal is digitised at high speed and at high resolution to allow low-error processing over the whole frequency range providing a three-times improvement in accuracy over purely analogue methods. Measurement set-ups are stored on amplifier cards or in external memory modules and the *MGC* gives either analogue or digital output. Control is by front panel or by computer via RS-232C, RS-485/422 or IEEE488 interfaces. The compact version is a two-channel instrument, but models are available with six, twelve or sixteen channels. HBM United Kingdom Ltd. Tel., 0181-420 7170; fax, 0181-420 7336.

Discrete active devices

High-voltage mosfet. High-voltage p-channel mosfets, the *Supertex TP2635* and *TP2640* are rated at maximum drain/source voltage of 350V and 400V, have low gate/source thresholds of 2V maximum and a guaranteed $R_{ds(on)}$ of 15Ω. 2001 Electronic Components Ltd. Tel., 01438 742001; fax, 01438 742002.

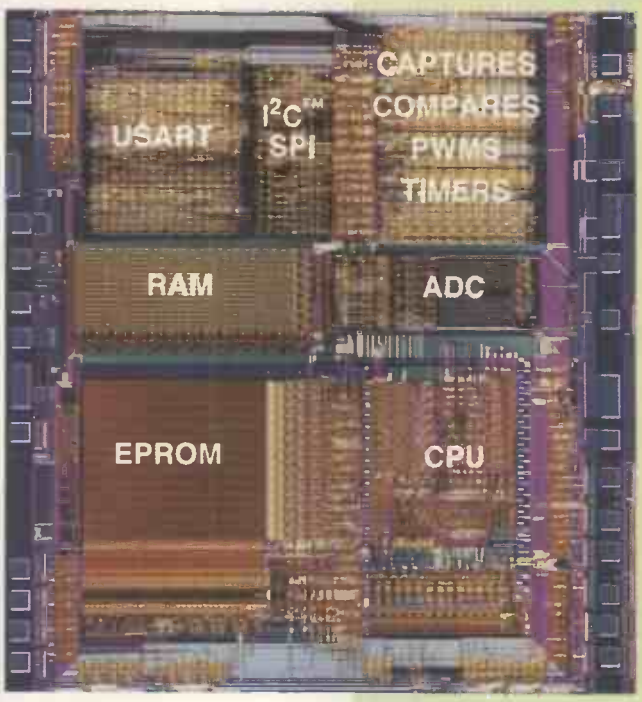
Digital signal processors

Serial i/o filter. Harris's *HSP43124* is a digital filter engine designed to take the burden of filter processing from a digital signal processor. Signal is input digitally and a second input takes the mix factors which are multiplied by the input samples. A multiply/accumulator performs the sum-of-products needed for the filter format selected by further inputs. Outputs go to an output formatter which rounds or truncates them to a selected width and generates timing and sync. signals for serial output transmission. The device will also serve in digital tuning. Dynamic range is over 100dB, operating on 24-bit words with 32-bit coefficients. Harris Semiconductor UK. Tel., 01276 686886; fax, 01276 682323.

Linear integrated circuits

Quad power drivers. In one package, each of four power drivers in the Elantec cmos *EL7412CM* sources or sinks a continuous 100mA into 4Ω. Response time is 20ns, with transient times of 10ns, matched to reduce timing errors. The chip takes 2mA from a single 5-15V supply. METL. Tel., 01844 278781; fax, 01844 278746.

Video buffer. *MAX4005* is a high-speed buffer with an internal, thin-film 75Ω resistor to prevent reflections when driving 75Ω cables. The input stage is a jfet, which takes only 10pA input current. Features include gain and phase errors of 0.11% and 0.03°, 60MHz, 0.1dB gain flatness, better than –60dB third-harmonic distortion, 1000V/µs slewing and 2ns settling to 0.1%. Rise and fall times are 350ps. Maxim Integrated Products UK Ltd. Tel., 01734 845255; fax, 01734 843863.



Memory chips

64Mb drams. Engineering samples of Micron Technology's 64Mb drams, organised as 16Mb by 4, are available. They are made in a four-poly, double-metal cmos process with channel lengths of 0.35µm. The *MTL4LC16M2A7* is available with access speed of 60ns, 8K refresh and fast-page mode in a 500mil 34-lead SOJ package. Micron Europe. Tel., 01344-360055; fax, 01344-869504.

Eeproms for SPI. Xicor's 8-64K serial eeproms in the *X25000* series support the Serial Peripheral Interface bus protocol, interfacing directly to the serial port of microcontrollers when in synchronous mode or to a separate serial interface for inter-chip transfers on some controllers. Selected areas of the memory can be protected. Micro Call Ltd. Tel., 01844 261939; fax, 01844 261678.

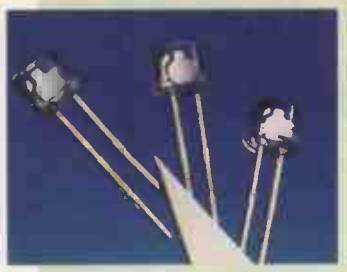
Microprocessors and controllers

Twin-*Pentium* processors. *TwinStar* multi-chip modules based on two 100MHz *Pentium* processors are being sampled by MicroModule. Each module is in a 347-pin package with a pinout that is a superset of the Intel Overdrive socket, needing only a 3.3V supply. *TwinStar* is validated with both Intel *8243nx* and Intel*82497/82492* chipsets and is in the process with another set. It complies with the MPS 1.1 standard. MicroModule Systems Inc. Tel., +1 408 864 7437; fax, +1 408 864 5950.

OTP microcontroller. *PIC16C74* by Microchip is a 40-pin, field-programmable 8-bit microcontroller that has an a-to-d converter and extensive comms facilities; it also has a 4K one-time-programmable program memory. Its risc core uses Harvard architecture with a 200ns cycle time and 35 single-cycle, 14-bit instructions. The a-to-d converter acquires in 16µs. Thirty-four pins are concerned with i/o functions, including an 8-bit asynchronous slave port for other controllers, a synchronous serial port for SPI or I²C/Access buses, a 5Mb/s usart, two pwm outputs at 80kHz and a 16-bit capture/compare facility with 200ns resolution. Arizona Microchip Technology Ltd. Tel., 01628 851077; fax, 01628 850259.

Frugal 16-bit microcontroller. Affording a saving of 50% in battery power over standard 5V microcontrollers, Toshiba's *TMP93CM40F* 16-bit chip has

Please quote *"Electronics World + Wireless World"* when seeking further information



Laser diode. Made by EG&G in Canada, the *C86137E* InGaAs pulsed laser diode uses a multiple quantum well design to give a peak output of 8W at a peak forward current of 25A and 10V; wavelength is 905nm. Price is under £10.00. Pacer Components Ltd. Tel., 01734 845820; fax, 01734 845425.

optimised CPU, 16Mbyte of internal memory and i/o cells that operate on 2.7-5.5V supplies at currents as low as 5mA at 3V and 12.5MHz. It has four-channel direct memory access. Toshiba Electronics (UK) Ltd. Tel., 01276 694600; fax, 01276 691583.

Cooler Pentia. Cirrus Logic offers the two-chip set *Golden Gate*, which reduces power consumption and heat generation of a *Pentium* by up to 80%, without impairing the microprocessor's performance. The company's subsidiary, PicoPower, uses the Power-on-Demand technique to reduce system power when the *Pentium* is idle, cycling power to the processor on and off in increments of 1ns,. Cirrus Logic Inc. Tel., 01727 872 424; fax, 01727 875919.

Mixed-signal Ics

Motor controllers. IR's new intelligent power modules lower the cost of motor control below that of discrete components or existing modules. Opto-isolators are eliminated, as are three of the four Isolated supplies normally needed. First in the family of devices, which contain an *IR2130* power IC with *Hexfred* diodes and Igbts, are the *IPM1560* and *IPM2060* 15A and 20A devices rated at 600V, to drive 1hp and 2hp motors. International Rectifier. Tel., 01883 713215; fax, 01883 714234.

Video encoder. Philips's *SAA7187* digital video encoder takes MPEG compressed data or digital YUV video and encodes it into ntsc or pal composite video or S-video signal. It generates subcarrier and colour modulation and inserts sync. signals; luminance and chrominance are filtered to RS-170-A and CCIR-624 requirements. Pixel data in various formats goes to one of three 8-bit wide ports, one of them also taking a microprocessor input when free from video. Philips Semiconductors (Eindhoven)..Tel., +31 40 722091; fax, +31 40 724825.

Optical devices

Blue leds. *Nichia* gallium nitride leds provide a bright blue light at a luminous intensity of 1000mcd, output being 1200mW at 20mA. Peak wavelength is 450nm with a viewing angle of 15-45°, depending on type. Packaging Is in standard 3mm and 5mm types. Hero Electronics Ltd. Tel., 01525 405015; fax, 01525 402383.

Oscillators

Crystal oscillator. IQD's *60 series* of surface-mounted oscillators measure 7.5 by 5mm by 1.6mm high and the thermal coefficient of the ceramic package matches that of the substrate in multi-chip modules, for which the oscillator is designed. Frequency coverage is 1.5-60MHz at stabilities of either ±50ppm or ±100ppm. Compatibility is with ttl or hcmos/ls-ttl, with or without tri-state operation. IQD Ltd. Tel., 01460 77155; fax, 01460 72578.

Power semiconductors

600V mosfets. New power mosfets from Toshiba are rated at 400-600V and have power loss reduction 0f 30% over earlier techniques. They are meant for use in lighting and switched-mode power supplies and offer an $R_{ds(on)}$ 15% lower and switching speed 25% faster than before. The 500V, 15A *2SK2150* has an on resistance of 0.29Ω, the 20A *2SK2057* showing only 0.24Ω. Both are in TO3P(N); there is also a 600V, 6A type in TO220. Toshiba Electronics (UK) Ltd. Tel., 01276 694600; fax, 01276 691583.

Power fets. New *Hexfet* power transistors by IR exhibit an $R_{ds(on)}$ of less than 50% that of existing devices of the same size; the 55V n-channel *IRF3205*, for example, has an $R_{ds(on)}$ of 8mΩ, the *IRL3803* in the 30V series showing only 6mΩ in both 4.5V and 10V, V_{gs} states, all in TO-220. P-channel devices show an $R_{ds(on)}$ only twice that of the n-channel types. International Rectifier. Tel., 01883 713215; fax, 01883 714234.

PASSIVE

Passive components

Metal-film resistors. Two ranges of Philips metal-film resistors cover resistance ranges of 24Ω-100kΩ (*MPR24*) and 4.99Ω-1MΩ (*MPR34*) to tolerances of ±0.05, 0.02 and 0.01% for the former and ±0.5, 0.25 and 0.1% for the latter. Those in the 24-200Ω range to ±0.1% tolerance are of low inductance. Dissipations of 125, 250 and 400mW are available. Gothic Crellon Ltd. Tel., 01734 788878; fax, 01734 776095.

Tantalum capacitors. Low equivalent series resistance is the feature of *AVX*'s new series of tantalum chip capacitors. With esr in the range 0.15-1Ω, the number of capacitors used to filter the output of switched-mode power supplies can be reduced. Ripple current rating is higher, which makes for lower temperatures and greater reliability. In 3V logic, any reduction in ripple and noise on the supply is helpful; the capacitors help to ensure that. AVX Ltd. Tel., 01252 770000; fax, 01252 770001.

Inclinometers. Two kinds of inclinometer by Control Transducers use optical and force-balance techniques. Optical types are either of the incremental variety, giving 7200 pulses/rev with ttl output and, optionally, an index pulse, or the absolute type providing 4096 pulses/rev, which have either 0-4096mV output or RS-232 serial interface port to drive up to 15 sensors on one SEI bus. Force-balance models are in five ranges from ±5.75° to ±90°, with an output of 0 to ±5V full scale. Non-linearity is ±0.005% and non-repeatability ±0.005%. Control Transducers. Tel., 01234 217704; fax, 01234 217083.

Resistor network. Using the Vishay-Sfernice *CNS* range of sip resistor networks, LSW offers a custom network production service in non-standard values from 50Ω to 1MΩ, the resistors being single or multiple with a common lead or in chains. Resistors exhibit a temperature coefficient of 10ppm/°C and 0.1% tolerance. LS Wiggins Ltd. Tel., 01243 826824; fax, 01243 860493.

Displays

Thin, mono vga. A new black and white vga display from Hitachi, the *LMG5378XUFC* offers the full vga 640 by 480 dot resolution and measures only 5.5mm thick, weighing 330g. That, together with a single 5V supply at 20mA, makes the device very suitable for portable equipment. Its features include a fluorescent backlight, an anti-glare screen and a wide viewing angle. Overall size Is 257.7mm by 174mm, with a display area of 196mm by 150mm. The recommended controller is the *HD66841*. Elger Technologies Ltd. Tel., 01928 579000; fax, 01928 579123.

Bright lcds. Three graphic lcds from Citizen use the super-twisted nematic (stn), passive-matrix technique, Citizen's 'chip-on-glass' technology and dual-scan addressing for faster refresh. *K6481L-FF* is a 4.7in unit for palm-top equipment; *K6483LFF* an upgrade of the 7.9in *K6480L-FF* with a thicker metal casing for better rf performance and a brighter backlight; and *G6489L-FF*, a 9.4in monochrome type measuring 5mm thick, with twin retardation control films for improved contrast. All provide 640 by 480 resolution and use a fluorescent backlight. Citizen Europe Ltd. Tel., 01753 584 111; fax, 01753 582 442.

Filters

Motor-drive filter. Schaffner has introduced a new type of filter, the *FN500*, to follow the output of 4-16A, 6-20kHz motor-drive inverters which, in the raw state, can cause a shortening of motor life by up to 50% due to high peak currents; leakage losses due to fast edges and stray parasitic capacitance in shielded cables; interference and therefore compatibility precautions; and acoustic noise. Schaffner says the filters provide a smooth output waveform to reduce or eliminate all these effects, for example reducing output pulse slewing rate from 8kV/µs to 400V/µs. Schaffner EMC Ltd. Tel., 01734 770070; fax, 01734 792969.

Hardware

Enclosures. Equipment enclosures from *Briticent* come in ranges of polycarbonate, ABS, polyester, steel, stainless steel for the food industry and aluminium and are of standard sizes or custom-made, complete with accessories. Sizes range from small boxes for push-button switches to floor-standing types. Options include inspection windows, vents, cover plates and specified machining and

drilling. A catalogue is offered. Briticent International. Tel., 01425 474617; fax, 01425 471595.

Instrumentation

Graphical multimeter. Fluke's *860 Series Graphical Multimeters* combine a dual analogue/digital readout with waveform display up to 1MHz, a 30h by 1s plot of readings with a graph of the stored result, in-circuit test of components and logic test to show transitions to 10MHz, frequency and dc average. Parameters determined by the meter readout are ac and dc voltage, current, resistance, conductance, capacitance, frequency, duty cycle, pulse width, period and decibels. Fluke UK Ltd. Tel., 01923 240511; fax, 01923 225067.

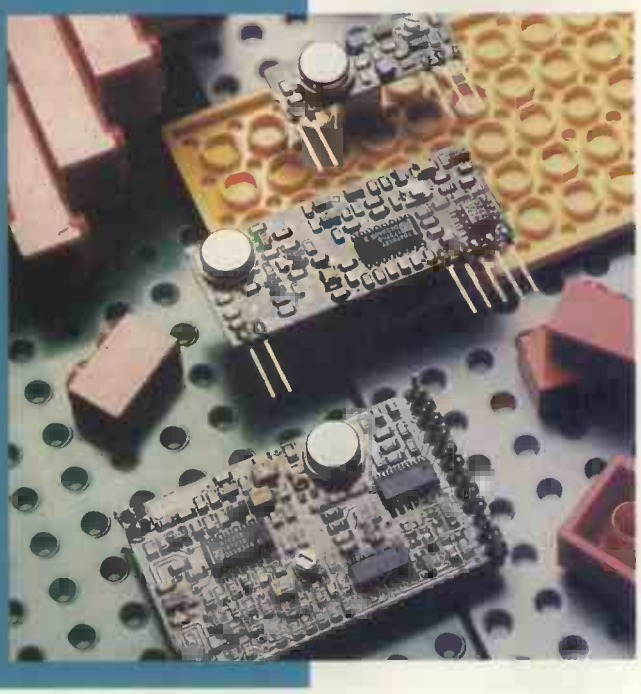
Radio communications products

Low-power RF links. LPRS has a matched pair of low-power radio telemetry transmitter and receiver modules for the transmission of analogue or digital data up to 200 metres. Both the *TXM-433-A* transmitter and *SILRX-433-A* receiver are pcb-mounted and operate at the standard European ETS 300-220 frequency of 433.92MHz (418MHz in the UK). Transmitter modulation bandwidth is 0-10kHz with an internal first-order low-pass filter, while the Rx needs only an antenna. Power to the transmitter is 10mA from 9V, although it accepts 6-12V, and that to the receiver is 15mA from 5V. Carrier detection signal appears in less than 3ms to allow power-saving circuitry to operate. Low Power Radio Solutions Ltd. Tel., 01993 709418; fax 01993 708575.

Mains dropout testing. Schaffner EMC offers the *NSG642* variable ac source, intended for use with, and control by, the *NSG1003* mains dropout generator, running the Windows-based *WIN1003* software. The *642* enables under and over voltage testing between 1V and 280V ac, changing output voltage at up to 120V/s to produce timed voltage dips as required by EN61000-4-11. Its two motor-driven transformers are rated at 16A continuous or 80A short-term. The combination also functions as a stable ac source for sensitivity and reliability testing. Schaffner EMC Ltd. Tel., 01734 770070; fax, 01734 792969.

Photometer. Tek's *LumaColor II* handheld photometer makes colour light measurement for colour matching and balance in television studios, crt manufacture and services such as street lighting, using the existing range of measuring heads. With available single-sensor heads, it measures luminance, illuminance, radiance or irradiance. It has a 10-channel memory for reference colours, rgb bargraphs helping to match colours with the reference. There is RS-232 control, output being either analogue or by RS-232. Tektronix UK Ltd. Tel., 01628 486000; fax, 01628 474799.

GSM test sets. Racal has two portable test sets, the *6103* for digital radio telephones and the *6113* for base transceiver stations. They retain the features of earlier instruments, but offer new features. Two PCMCIA cards in the *6113* allow test sequences to be stored and recalled and enable operating code to be loaded into the instrument to lengthen its operating life. *6103* has manual and automatic operation and will check a GSM telephone in under 30s. Both can be remotely controlled and the 6113 runs a Windows control package. Racal Instruments Ltd. Tel., 01734 669969; fax, 01734 262121.



Multimeter/recorder. Hioki offers the *8220 Multi HiPlay* combined digital multimeter and recording instrument, which presents changes in dual-channel voltage and current readings on an lcd graph. The instrument simultaneously displays on the 5in lcd and stores readings for up to six days, giving a graph of variations over time. A cursor gives a numerical reading of values from the graph, including minimum, maximum and average values, date and time. 01734 786911; fax, 01734

Literature

Crystal products. IQD's 1995 *Crystal Products Data Book* is now available, having 330 pages. Additions since the last one include a digital temperature-compensated oscillator, a range of surface-mounted filters and ceramic-packaged SM crystals. IQD Ltd. Tel., 01460 77155; fax, 01460 72578.

PCB standard. British Standards has published BS EN 60249, which is concerned with base materials for pcb manufacture. Spec. 6 and 7 are on phenolic cellulose paper copper-clad sheet burning tests, horizontal and vertical. The standard supersedes BS 4584 and costs £44 or £22 to subscribing members. BSI Customer Services, Publications, 389 Chiswick High Road, London W4 4AL.

Consumer ICs. In consumer ICs, GEC Plessey concentrates on rf front ends for broadcast, cable and satellite television, vcrs and teletext. Its *Consumer IC Handbook* describes the company's products in these areas in detail and contains application notes with practical examples. Gothic Crellon Ltd. Tel., 01734 788878; fax, 01734 776095.

Market intelligence. Frost and Sullivan has new catalogues of market research reports on *Sensors, instrumentation and control* and *Electronics and components*. Reports contain an average of around 320 pages and describe how a particular market is composed and who the market leaders are, growth or otherwise of a market, company profiles, competitive influences and technology trends. Prices vary from around £650 to £3000. Frost & Sullivan. Tel., 0171 730 3438; fax, 0171 730 3343.

Materials

Green degreaser. *Vaposol* by Croftshaw is a replacement for chlorinated hydrocarbon vapour degreaser, such as 1.1.1 trichlorethane, which is not only more friendly to the environment but also saves time and money. It cleans by condensation in one tank, so that parts are clean and dry in five minutes at low temperature. Vaposol can be used with existing equipment. Croftshaw Solvents Ltd. Tel., 0181 6985556; fax, 0181 6974614.

Navigation systems

GPS from GPS. GEC Plessey Semiconductors has made available a complete Global Positioning System development environment that

Interfaces

PCI-PCMCIA interface. From Cirrus Logic, the *CL-PD6729* is claimed to be the first mixed-voltage PCI-to-PCMCIA host adaptor to control two independent PCMCIA sockets, allowing the use of 5V and 3.3V peripherals simultaneously. The dual-slot host adaptor gives a direct connection to the PCI system bus, supporting both PCI interface for x86 systems and *PowerPC* systems. Low power consumption is achieved by a suspend mode and an automatic low-power dynamic mode which stops transactions on the PCMCIA bus, stops clock distribution and turns most of the internal circuitry off. There is full PCMCIA compatibility and bios-level software to interface host adaptor to host. Cirrus Logic Inc. Tel., 01727 872424; fax, 01727 875919.

converts a 486 pc into a 12-channel GPS receiver for learning the system and product development. It includes a chipset and a set of GPS tracking and acquisition software for 12-channel parallel processing in C, available as source and executable code. The chipset includes the *GP1010* rf downconverter, *DW9230* 35.4MHz IF saw filter and two six-channel *GP1020* correlators, all on a daughter card mounting on the main card with an ISA interface to the host. The system also includes a patch antenna, cables, software and a manual. GEC Plessey Semiconductors Ltd. Tel., 01793 518510; fax, 01793 518582.

Production equipment

Marking machine. Rejafix has the *Hotmarker Model H.402*, a manually operated bench machine for the permanent identification marking of cable sleeving and tube to the BS.3858 standard. The required mark is dialled into the machine, which gives hot-foil, instant-drying print and avoids the need to hold stocks of specific markings. A number of available print wheels are either flat or curved for tubing and some models are able to cut the tube or cable to length after printing. Rejafix Ltd. Tel., 0181 5602224; fax, 0181 5608774

Power supplies

Pentium power. First in a range of dc-to-dc converters designed to supply power to Intel's 3.3V P54C-VR Pentium processor, the Semtech *MP54C-1B* is a 68% efficient 15W device operating over the 4.75-5.5V input range and needs no heat sink. It provides linear regulation, overvoltage, short-circuit and thermal protection and a signal to indicate when the output is within limits. Semtech Ltd. Tel., 01592 773520; fax, 01592 774781.

Step-down controllers. *MAX796-799* high-power step-down controllers drive external n-channel mosfets to power cpus at 95% efficiency, logic-controlled shut-down current being 1.2µA. *MAX797/8* have a logic-controlled, synchronisable, fixed-frequency pwm mode to reduce noise in communications equipment, while *MAX796/9* use a secondary feedback input for transformer-based application, to improve cross-regulation of auxiliary outputs. Input range is 4.5-30V and outputs are 2.9V, 3.3V and 5V at up to 10A. Maxim Integrated Products UK Ltd. Tel., 01734 845255; fax, 01734 843863.

Intelligent SMPS. Vero's *ISI-POWER* switched-mode power supply is claimed to be the first 19in rack-mount psu with an intelligent controller, which allows programming, control and interrogation from a pc via an RS-232 serial link. It is a 180W unit in a 6U by 6HP module, modules available providing 3.3V, 5V, 12V, 15V and 24V from an autoranging universal input. Monitoring by pc includes input, output and sense voltages and output current; a temperature probe can be fitted, with temperature limits set remotely to activate fans. Any problem causes an alarm box to open on the computer screen. Vero Electronics Ltd. Tel., 01489 780078; fax, 01489 780978.

DC-DC converters for lcds. Surface-mount dc-to-dc converters from *Murata* are designed to power lcds, voltage from the external power source being converted within the display unit. They are designed for use with simple monochromatic lcds and are in a metallic case to reduce radiation. Output on/off switching is provided. Murata Electronics (UK) Ltd. Tel., 01252 811666; fax, 01252 811777.

Power and protection. Fiskars' *PowerRite Plus* uninterruptible power supplies provide protection for small systems, incorporating a communications interface that allows the use of Lansafe III power-management software to guard pcs and workstations, point-of sale equipment, remote lan nodes and others against power problems. The units also have the company's Advanced Battery Management functions to extend battery life by up to 30%, battery test and warning of impending battery trouble. Three models provide 250VA, 400VA and 600VA. Fiskars Electronics Ltd. Tel., 01734 306600; fax, 01734 305868.

Television components

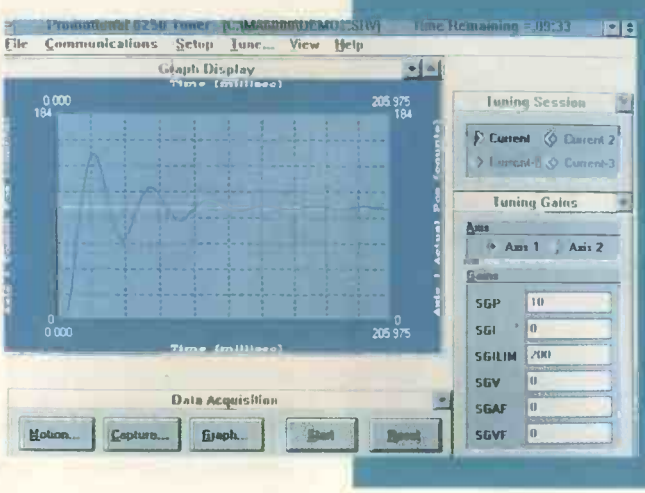
Image enhancement. *TDA9170* by Philips is a single-chip video processor that improves the quality of the picture on television receivers using the standard luminance and colour-difference interface (yuv). It uses adaptive, non-linear amplification of the y signal, based on real-time analysis of the picture content to enhance contrast to give an apparently sharper picture and better detail in dark areas. There is also adjustable gamma correction, automatic u and v correction and control over the picture area in which black-level detection and the picture analysis are carried out. Philips Semiconductors (Eindhoven). Tel., +31 40 722091; fax, +31 40 724825.

Transducers and sensors

Monostable solenoid. BLP's *PED Series 68* direct acting solenoids are now available in a monostable version having an international standard frame size. Power rating is 3.5W at 240V dc maximum, the coil pulling a load of 0.4kgf at a 10mm stroke. Custom-designed types are offered. BLP Components Ltd. Tel., 01638 665161; fax, 01638 660718.

Vision systems frame grabber. DataCell has upgraded its *J-Tool* colour Sbus frame grabber to provide 4416 by 3456 pixel resolution at 24 bits/pixel. When used with a Sun *SPARCstation* and a JVC *TK-F7300* camera, the *SS2200* J-Tool card allows small areas to be analysed at this very high resolution. J-Tool supports TIFF image storage and capture, providing live image display in an X-window for manual focus and set-up. DataCell. Tel., 01628 415415; fax, 01628 415400.

Servo set up. *Servo Tuner* is an add-on software module to work with Compumotor's Windows-based *Motion Architect* software, together providing graphical feedback of real-time motion information and an easy method of setting tuning gain and other characteristics in the 6000 Series of servo controllers. The package allows the drive system to be tuned without the position loop and the position loop tuning with graphical feedback to show exact system motion, automatically generating set-up code, editing and executing motion-control programs and creating a test panel. Parker Hannifin plc, Digiplan Division. Tel., 01202 699000; fax, 01202 600820.



COMPUTER

Computer board-level products

Graphics for VME. Syntel's *SYN-B301* is a graphics controller with a *GDS5422* core, capable of 24-bit true-colour imaging. Its video interface is programmable so that video and sync. signals can be arranged to cope with a range of requirements under software control. Resolution up to 1280 by 1024 is offered and video frequencies are generated by phase-locked loop, programmable between 7MHz and 80MHz. Video memory is 1Mbyte, expandable to 2Mbyte. There is audio output and the serial mouse is Logitech-compatible. Syntel Microsystems. Tel., 01484 535101/2/3; fax, 01484 519363.

Small pc board. DSP Design offers the *GCAT 6000*, an update on earlier *GCAT* boards with more functions and still the size of a credit card. Functions include PCMCIA Type II interfacing, an a-to-d converter, 1Mb of rom and 8Mb of dram. It forms a reasonably priced alternative to custom boards in embedded microcontroller applications. Engineers can configure i/o, peripheral and graphic processor modules with the help of a development system. Two PCMCIA devices, for example an Ethernet/modem and hard disk, may be simultaneously connected to the double-stack connector. Ports include keyboard, two serial ports and lcd and crt interface, higher-resolution and electroluminescent displays also being supported. The board draws 75mA from 5V on fast run and 50µA suspended. DSP Design. Tel., 0171 482 1779; fax, 0171 482 1773.

Data communications

200Mbyte/s for VMEbus. Using PEP's *AutoBahn Starter Kit*, designers of VMEbus systems can obtain a data transfer rate of up to 200Mbyte/s. The kit includes AutoBahn Spancelvers, 15-slot backplane, host cpu, drivers, notes and test data, and may also be used for non-VMEbus hardware. Processing power is provided by PEP's VM30 *68EC030/68302* single-board computer giving 16Mips. PEP Modular Computers. Tel., 01273 441188; fax, 01273 441199.

Plug-and-play modem chips. Users of Sierra's *SC11140* fax/modem chipset will have no need to spend time on modem and computer adjustments, since the chips automatically configure an ISA modem. The controller chip queries system resources and determines which com ports and interrupts are available, also incorporating the logic to add voicemail and Windows MCI-compatible business audio to a V.32bis modem. It is suited for Windows 95, when that is available. Sierra Semiconductor bv. Tel., +31 73 408 888; fax, +31 73 423 155.

Dual-port serial boards. Amplicon Liveline has six *200 Series* serial communications boards for PC XT or AT(ISA) bus computers, each having two serial ports conforming to RS-232, RS-422 or RS-485 and the

choice of opto-isolation. All have flexible base address and interrupt to allow each port to be independently addressed at locations from 000 to $7F8_{16}$ at any 8-bit boundary. Each serial port has a 16-byte input fifo and a 16-byte output fifo in the uart, both being software-selectable. Amplicon Liveline Ltd. Tel., 0800 525 335 (free); fax, 01273 570215.

Wireless modem. Newest member of Rockwell's family of wireless communications products is the *RC32ACC*, a cellular digital packet data (cdpd) V.32bis data modem two-chip set, allowing landline, cellular or digital packet radio communications. It uses the same cellular network for voice and data and delivers services including e-mail and fax in one device and is pin-compatible with the earlier *RC144ACL* wireline data/fax modem. Rockwell International Corp. Tel., 0181 577 2800; fax, 0181 577 2257.

Crash protection for networks. GEC Plessey offers the *PCA873*, an IC for the protection of networks against low-frequency disturbances on network signals caused by losses in transformers. This is a particularly severe effect on fast signals such as those in Ethernet at 100Mb/s or ATM at 155Mb/s. The IC also protects against the kind of data frame that accentuates the 'base-line wander' and allows high-speed networks to use unshielded and shielded twisted-pair copper cables. GEC Plessey Semiconductors Ltd. Tel., 01793 518510; fax, 01793 518582.

Mass storage systems

Sram PCMCIA card. *Centennial* has the first sram PCMCIA cards with a rechargeable lithium battery, which is charged each time the card is inserted. A range of 3.3V and 5V flash, mask-rom and otp cards is available. The company also offers a GPS receiver housed in a Type 2 PCMCIA enclosure. Trident Microsystems Ltd. Tel., 01737 765900; fax, 01737 771908.

Software

Speech compression. GSM speech-compression software is obtainable as source code for the AT&T *DSP32C* signal processor working in VME or Sbus systems from Bores. The software costs £4000, without further royalty payments. It will run on a multi-processor VME system with multi-channel speech i/o. Bores Signal Processing. Tel., 01483 740138; fax, 01483 740136.

Operating system simulator. A Windows version of Enea Data's *OSE/SIM* is now available, which allows developers of embedded applications using the *OSE* real-time operating system to debug and test software independently of hardware and even before the hardware exists. The package does the same as the existing version, but has Hypertext help and simplified signal and process entry. It supports 8-bit, 16-bit and 32-bit microprocessors. When combined with a native C compiler and source-level debugger, the package forms a complete development environment and is also available for pc-dos, Unix and VAX/VMS hosts. Reflex Technology Ltd. Tel., 01494 465907; fax, 01494 465418.

Network power management. Fiskars' *LanSafe III* and *FailSafe III* are uninterruptible power supply software packages that monitor network power and control shutdown and rebooting of networks. It shuts down workstations, servers, bridges and the other devices to a defined schedule, saving data and flushing system caches to disk. *LanSafe III* provides network functions on all major operating systems and *FailSafe III* on single-user environments such as Windows. Fiskars Electronics Ltd. Tel., 01734 306600; fax, 01734 305868. ■

6805/HC05 C cross-compiler. Pentica claims its true C compiler for the Motorola 6805 processor to be the first available. *Hi-Tech C* produces compact and efficient code, is Ansi-compliant and creates complex interrupt-driven applications in C. It supports prototypes and variable argument lists, function pointers, long arithmetic, floating points, bit fields, structures, unions and a full C code printf(). There is full control over variable placement including i/o ports at fixed addresses, and internal or extended ram. Interrupts may be declared in C and called from hardware interrupts; generated code saves and restores the processor state, handles the interrupt and returns. Macros initialise, enable and disable interrupts from C and interrupt vectors can be changed 'on the fly'. A compiled stack preassigns static memory addresses to local variables and function arguments, overcoming the *6805*'s limitation of having no addressable stack, which makes it normally impossible to run a C run-time model with stack-based functions. Pentica Systems Ltd. Tel., 01734 792101; fax, 01734 774081.

FREE TO SUBSCRIBERS

Electronics World offers you the chance to advertise

ABSOLUTELY FREE OF CHARGE!

Simply write your ad in the form below, using one word per box, up to a maximum of twenty words (remember to include your telephone number as one word). You must include your latest mailing label with your form, as this **free** offer applies to private subscribers only. Your ad will be placed in the first available issue.

This offer applies to private sales of electrical and electronic equipment only.

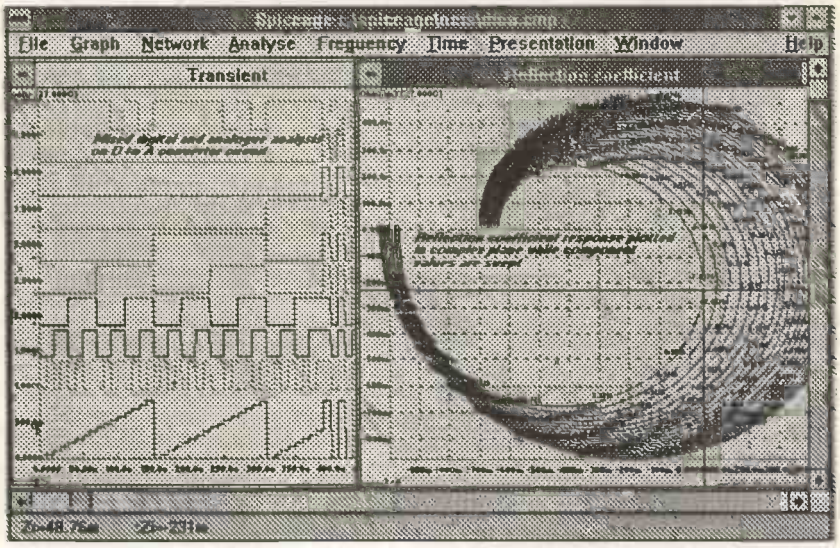
Trade advertisers should call **Malcolm Wells on 081-652 3620**

All adverts will be placed as soon as possible. However, we are unable to guarantee insertion dates. We regret that we are unable to enter into correspondence with readers using this service, we also reserve the right to reject adverts which do not fulfil the terms of this offer.

Please send your completed forms to:

Free Classified Offer: Electronics World, L329, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS

Look what's new in version 4 of SpiceAge for Windows™



- DDE link with Modelmaker, the utility that synthesizes opamps, transformers, attenuators and transistor library models
- Reflection coefficient analysis
- Noise analysis
- Improvements to digital displays
- Auto-time interval setting option
- Time optimisation in relaxed circuits
- Faster quiescent calculations
- SPICE repertoire enhancements for ASICS
- DDE link with ***GESWIN***, new schematic editor (optional extra) for SpiceAge
- Windows™ wave (.wav) file compatibility. Multi-media users can listen to their waveforms or capture sound samples for Fourier analysis or filtering. Binary output option makes ROM programming easy.
- PWL non-linear enhancements saves calculating polynomial coefficients for those awkward functions.

Make sure you know what you are missing by asking us for a copy of the demonstration program and booklet or talk us through your small circuits for a sample simulation.

Please contact Those Engineers Ltd, 31 Birkbeck Road, LONDON NW7 4BP.
Tel 0181-906 0155, FAX 0181-906 0969.

Those Engineers Ltd

CIRCLE NO. 135 ON REPLY CARD

STEREO STABILIZER 5

- Rack mounting frequency shifter for howl reduction in public address and sound reinforcement.
- Mono version, box types and 5Hz fixed shift boards also available.

★ Broadcast Monitor Receiver 150kHz-30MHz.
★ Advanced Active Aerial 4kHz-30MHz.
★ Stereo Variable Emphasis Limiter 3.
★ 10-Outlet Audio Distribution Amplifier 4.
★ PPM10 In-vision PPM and chart recorder, also as expansion board for Acorn Computers.
★ Twin Twin PPM Rack and Box Units.
★ PPM5 hybrid, PPM9 microprocessor and PPM8 IEC/DIN −50/+6dB drives and movements.
★ Broadcast Stereo Coders.
★ Stereo Disc Amplifiers.
★ Peak Deviation Meter for FM broadcasting

SURREY ELECTRONICS LTD
The Forge, Lucks Green, Cranleigh, GU6 7BG.
Telephone: 01483 275997. Fax: 276477.

Field Electric Ltd.

Tel: 01438-353781 Fax: 01438 359397
Mobile: 0836-640328/0860-213370
Unit 2, Marymead Workshops,
Willows Link, Stevenage, Herts, SG2 8AB.

7" colour monitor, cased. Low voltage 12VDC with data	£24 c/p £8.00
Sony Panasonic 1.44Mb refurb disk drives	£10
14" SVGA monitor 1024x768-28 dot pitch refurbs 1st brand	£130
360/720K 5.25" TEAC BBC compat. disk drives	£9.50 C/P £3.50
High quality 750HM video cable 100 metre+ reel	£22.00 C/P £6.00
Sony 9" colour monitor Trinitron super fine pitch model KTM 1000ub Cased with data for RGB	£50
102 key AT enhanced keyboard with PS2 type plug	£10 C/P £4
Intel flash memory cards 1Mb to 4Mb from	£80
Test equipment: please ring for C/P details	
HP X532B frequency meter	£165
HP 1740A 100MHz oscilloscope dual chn: with 3rd chn	£300
HP 1332 X-Y display with options 215/300/315/570/631	£150
HP 693D sweep oscillator 4-8 GHz	£95
HP 10013A probe	£24.50 C/P £3.50
HP 331A distortion analyser	£150
HP 415E SWR meter	£195
HP 9872A 4 pen plotter	£225
HP 3551A transmission test set	£725
HP 1610B Logic State Analyzer with Pods	£135
HP 1611A Logic State Analyzer	£125
TEK: 06 7-502 standard amplitude calibrator	£100
TEK: swept frequency converter 015-0107-00	£59
TEK: 7D12 A/D converter plug in	£115
TEK: 455 o'scope 50MHz delay	£350
TEK TM504 mainframe	£125
TEK 184 time mark generator	£95
TEK: 2215A 60MHz o'scope with carry case	£395
TEK: D10 o'scope mainframe	£95
TEK: DAS9100 digital analysis system	£295
TEK: 067 0508 00. 50 ohm amplitude cal.	£95
TEK: 146 NTSC test signal gen.	£475
TEK: 7A18 dual trace amp	£125
TEK: 7D15 225MHz universal timer counter	£130
TEK: 7S11 sampling unit	£140
TEK: 453 o'scope 50MHz dual beam	£250
Sony video cassette recorder u-matic BVU 850	£1.5K
Gould OS4000 digital storage o'scope	£195
Fluke 8800A digital multimeter	£70
Calrec ZN1232 Desk PSU	£85
Fluke 8010A digital multimeter	£105
AEI Gauss meter FB22 form with probe	£117
Farnell B30/20 0-30 VDC 20A linear switched	£250
Sorensen SRL 40-12 0-4 VDC 0-12 metered 115 VAC input	£95
Systron Donner pulse gen: 100C	£95
EH microwave swept oscillator 574-1 7-12.4GHz	£295
Hydrostatic stability indicator	£500
Hughes Model 639 scan conversion memory	£300
Complot series 7000 digitizer tablet with Complot series 7000 digitizer	£225
Philips PM 8940 isolation amp etc	£85
Wayne Kerr VHF admittance bridge B801	£85
Advance inst: low distortion LF oscillator SG68A	£50
DLi delay gen: DG100	£80
Marconi TF 2602 diff: DC voltmeter	£65
Bromma LKB 2210 recorder 1-channel	£85
SLO-SYN HS25 stepper motor new & boxed 45oz in torque	£8.95 C/P £4.00
Fluke 893A AC-DC diff voltmeter	£295
General Radio 1433-H decade resistor	£135
Borg-Warner SWR Ind: M401	£120
Honeywell 1806A Visicorder	£185

PLEASE ADD 17.5% VAT. TO ORDER: RING FOR C/P PRICES NOT SHOWN: OFFICIAL ORDERS AND OVERSEAS ENQUIRIES WELCOME

CIRCLE NO. 136 ON REPLY CARD

CLASSIFIED

TEL 0181 652 3620 FAX 0181 652 8956

ARTICLES FOR SALE

DA 1519A AMPLIFIERS
2 x 11 watt stereo amplifier chips in 9 pin SIL plastic packages 1 – 9 £2.00 each: 10+ £1.50 each: postage and VAT included. Phone for volume discounts:
Tel: 0959 577632
Ken Barker: 18 Shipfield, Tatsfield, Westerham TN16 2AU

TURN YOUR SURPLUS TRANSISTORS, ICS ETC, INTO CASH
Immediate settlement.
We also welcome the opportunity to quote for complete factory clearance.
Contact:
COLES-HARDING & CO, Unit 58, Queens Road, Wisbech, Cambs. PE13 2PQ
ESTABLISHED OVER 15 YEARS
Buyers of Surplus Inventory
Tel: 01945 584188 Fax: 01945 475216

VALVES, and CRTs FOR SALE

ONE MILLION VALVES stocked for Audio, Receiving, Transmitting & RF Heating. Rare brands such as Mullard & GEC available. Also MAGNETRONS, KLYSTRONS, CRTs and SOCKETS.
Large stocks of Russian & Sovtek items.
Please ask for our free catalogues of valves or CRTs.

VALVES, etc. WANTED

All types considered but especially KT88/PX4/PX25 (£45), KT66 (£30), KT77/EL34/EL37 (£10), ECC81/ECC83 (£3). Valves must be UK manufacture to achieve prices mentioned. All VALVE-ERA EQUIPMENT such QUAD, LEAK, GARRARD 301.
If possible, send a written list for a prompt decision.
BILLINGTON EXPORT LTD., 1E Gillmans Ind. Estate, Billingshurst, Sussex RH14 9EZ.
Tel: 01403 784961 Fax: 01403 783519
VISITORS STRICTLY BY APPOINTMENT. **MINIMUM ORDER £50 plus VAT**

ARTICLES WANTED

WE WANT TO BUY !!

IN VIEW OF THE EXREMELY RAPID CHANGE TAKING PLACE IN THE ELECTRONICS INDUSTRY, LARGE QUANTITIES OF COMPONENTS BECOME REDUNDANT. WE ARE CASH PURCHASERS OF SUCH MATERIALS AND WOULD APPRECIATE A TELEPHONE CALL OR A LIST IF AVAILABLE. WE PAY TOP PRICES AND COLLECT.
R.HENSON LTD.
21 Lodge Lane, N.Finchley, London N12 8JG.
5 Mins, from Tally Ho Corner.
TELEPHONE
081-445-2713/0749
FAX 081-445-5702.

WANTED
High-end Test Equipment, only brand names as Hewlett-Packard, Tektronix, Rhode & Schwarz, Marconi etc. Top prices paid.
Please send or fax your offer to:
HTB ELEKTRONIK
Alter Apeler Weg 5,
27619 Schiffdorf, West Germany
TEL: 01049 4706 7044
FAX: 01049 4706 7049

WANTED
High-end Test, Communication & Computer Equipment. **Top prices paid.**
Please send or fax your offer to:
Steigerwald GmbH
Neusserstrasse 9, 80807 Munich
South Germany
Tel: 01049 89 3615833
Fax: 01049 89 3615899

WANTED
Test equipment, receivers, valves, transmitters, components, cable and electronic scrap and quantity. Prompt service and cash.
M & B RADIO
86 Bishopgate Street, Leeds LS1 4BB
Tel: 0532 435649
Fax: 0532 426881 9956

SERVICES

DESIGN SERVICES
Software Design: High and Low Level.
Hardware Design: Analogue, Digital, Micro and Embedded.
PCB, Schematic and Production Drawings.
Prototyping and Feasibility services.
Archimedes Custom Equipment: Tel 0974 282670

FREE CLASSIFIED

WANTED: PRE-WAR television. Jac Janssen, Hogeham 117D, NL-5104JD DONGEN, Netherlands. Tel: 01031 1623 18158, Fax (office): 01031 13 624664.

RF DESIGN CONSULTANCY
☐ Design and Development
☐ Technical Advice
☐ CAD
WATERBEACH ELECTRONICS LTD
34 Providence Way, Waterbeach
Cambridge CB5 9QJ
Tel: 0223 862550 Fax: 0223 440853

ADVERTISERS PLEASE NOTE

For all your future enquiries on advertising rates,

Please contact Malcolm Wells on

Tel: 0181-652 3620
Fax: 0181-652 8956

CLASSIFIED

TEL 0181 652 3620 FAX 0181 652 8956

ARTICLES FOR SALE

Cooke International
SUPPLIER OF QUALITY USED TEST INSTRUMENTS

ANALYSERS, BRIDGES, CALIBRATORS, VOLTMETERS, GENERATORS, OSCILLOSCOPES, POWER METERS, ETC. ***ALWAYS AVAILABLE***

ORIGINAL SERVICE MANUALS FOR SALE
COPIES ALSO AVAILABLE

EXPORT, TRADE AND U.K. ENQUIRIES WELCOME, SEND LARGE "A3" S.A.E. + 50P POSTAGE FOR LISTS OF EQUIPMENT AND MANUALS.

ALL PRICES EXCLUDE VAT AND CARRIAGE
DISCOUNT FOR BULK ORDERS *SHIPPING ARRANGED*

OPEN MONDAY-FRIDAY 9AM-5PM

Cooke International
ELECTRONIC TEST & MEASURING INSTRUMENTS
Unit Four, Fordingbridge Site, Main Road, Barnham, Bognor Regis, West Sussex, PO22 0EB

Tel: (+44) 0243 545111/2 Fax: (+44) 0243 542457

EQUIPMENT & ACCESSORIES PURCHASED
CIRCLE NO. 160 ON REPLY CARD

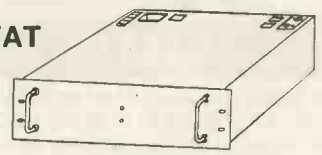
19" Rack Mounting Switch Mode Power Supply
By FARNELL INSTRUMENTS F2667
P.O. [B.T.] 164
MONARCH 250C SYSTEM

990 WATTS MODULAR CONSTRUCTION

+5 volt 48 Amp
+12 volt 8 Amp + Ringer Module Capable of Ringing 12 Telephone Bell Loads
−12 volt 5 Amp
−50 volt 8 Amp
Dimensions H125 D500 W485mm Weight 13.5KG

BRAND NEW IN ORIGINAL PACKING

PRICE £199.00 + VAT
UK Mainland
Carriage £12 +VAT



R. Henson Ltd.

21 LODGE LANE
LONDON N12 8JG
TEL: 081-445 2713/0749
FAX: 081-445 5702

INDEX TO ADVERTISERS

	PAGE		PAGE
Antex Electronics	90	Lab Center	95
BK Electronics	111	M&B Electrical	133
Bull Electrical	166	M&B Radio (Leeds)	112
Citadel Products Ltd	IFC	Mejdaf Europe Ltd	148
CMS	154	MQP Electronics	152
Crossware Products	97	Number One Systems	150
Dataman	BC	Olson Electronics Ltd	121
Devantech Ltd	150	Pico Technology	159
Display Electronics Ltd	93	Powerware	152
Field Electric Ltd	172	Ralph Electronics	176
Flash Designs	111	Research Communications	97
Halcyon Electronics	159	Seetrax Ltd	112
Henry's Audio Electronics	159	Smart Communications	IBC
Hitex (UK) Ltd	90	Stewart of Reading	97
ICE Technology Ltd	101	Surrey Electronics	172
Iosis	150	Technology Sources Ltd	126
John Morrison (Micros)	90	Telnet	141
Johns Radio	118	Those Engineers Ltd	172
JPG Electronics	152	Tsien Ltd	158
Kestral Electronic Components	148		
Keytronics	106		

RF & MICROWAVE

Permanent and contract opportunities for engineers and technicians in Cellular, Civil, Military, Satellite, Communications, Radio and Microwave Engineering.

Individual specialists or large teams supplied.

Cliveden Consultancy Services plc
92 Broadway,
Bracknell, Berks, RG12 1AR.
Tel 01 344 489 489. Fax 01 344 489 505.

Offices in London, Manchester, Southampton, Stevenage, Crawley, Brussels

CLIVEDEN
Technical Recruitment
Cliveden Consultancy Services plc

Established 1977. FRES MEMBER.

Managing Director: Roger Howard C. Eng. M.I.E.E.

SPECTRUM ANALYSERS

IFR A7550 portable synthesized spectrum analyser 10kHz-1GHz with GPIB and Tracking Generator options £4500
HP141T 18GHz system, (8552B/89555A) £2000
HP3580A 5Hz-50kHz audio spectrum analyser £1500
HP8558B 100kHz-1.5GHz spectrum analyser £2500
ANRITSU MS62B 1700MHz £2000
TEKTRONIX 492 50kHz-220CHz (extendable with external mixing to 220GHz). With opts 2&/, digital storage & 100Hz resolution £5250 or basic 492 with no options. £4500.

MARCONI INSTRUMENTS

2019 AM/FM synthesized signal generator 80kHz-1GHz £1750
2019A as above, improved spec £1950

2022D synthesized signal generator £1950
2438 520MHz universal counter/timer £200
2828A/2829 digital simulator/analyser £1000
2955 mobile radio test set ALL SOLD £3000
2955A + 2960 cellular adaptors ALL SOLD
6059A signal source 12-18GHz £750
6460/6420 power meter 10MHz-12.4GHz 0.3uW-10mW £350
893B audio power meter £350
OA2805A PCM regenerator test set £750
TF2910/4 non-linear distortion (video) analyser £500
TF2910 TV interval timer £250

RALFE · ELECTRONICS

36 EASTCOTE LANE, S. HARROW, MIDDLESEX HA2 8DB
TEL: 081-422 3593. FAX: 081-423 4009

NOW IN 40th YEAR

DISTRIBUZIONE E ASSISTENZA, ITALY: TLC RADIO, ROMA (06) 871 90254

TEST EQUIPMENT

ANRITSU ME518A pcm portable error rate test set £2500
BRUEL & KJAER 2511 vibration meter set/1621 filter £2250
BRUEL & KJAER 2307 level recorder £1000
BRUEL & KJAER 2317 portable level recorder £1850
BRUEL & KJAER 1618 band pass filter £750
BRUEL & KJAER 3513 portable vibration analyser £3500
BRUEL & KJAER 2308 X-Y recorder £750
AVO RM215L-2 insulation & breakdown tester £650
DATRON 1065 digital multimeter £550
DRANETZ 626 mains disturbance analyser/2 x PA-6001 £750
FARNELL 2081/100 100W RF power meter £325
FLUKE 1722A instrument controller (IEEE) £1000
RACAL 9009 automatic modulation meter £350
RACAL 9082 synthesized AM/FM signal generator 5-520MHz £600
RACAL 9300 RMS voltmeter -80dB to +50dB £325
RACAL V-STORE 16, 16-chan instrumentation recorder £9500
RACAL-DANA 9302 RF milli-voltmeter 1.5GHz £450
RACAL-DANA 9303 level motor, digital £1000
ROBERTS & ARMSTRONG f/o-cable end-cut measure unit £500
RHODE & SCHWARZ SMG signal generator £4000
TEKTRONIX 1503C/03/04/05/06 TDR cable tester £3250
TEXTRONIX 576 and 577 transistor curve tracers ea £1750
TAU-TRON MN302/MB302N bert £1000
WAYNE KERR 6245 precision component analyser £3000
WAYNE KERR B905 automatic precision bridge £950

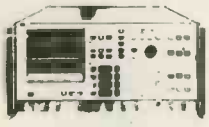
• ralfe electronics • exclusively professional T&M

FLUKE 1501B INSTRUMENT CALIBRATOR
with options: Wide Band/GPIB and RS232 interfaces. Price including current manufacturers calibration **£6750.**

EXPORTS ARE OUR SPECIALITY. ORDER WITH CONFIDENCE – FULL SERVICE AVAILABLE. WE CAN FIX LISTS AND SHIP WORLDWIDE.

RACAL V-STORE
16 channel instrumentation recorder with GPIB interface. **£9500.**

HEWLETT PACKARD



331A distortion meter £200
339A distortion meter £1500
3400A voltmeter 10Hz-10MHz £250
3335A synthesizer/level generator with option 01 £2500
3336A level generator £2000
3552A transmission test set £1000
3586A selective level meter £2500
415E swr meter £350
4274A multi-frequency (100Hz-100kHz) LCR component meter £4000
4275A multi-frequency LCR component meter £5000
432A/478A microwave power meter 10MHz-10GHz £400
432A/R486A uwave power meter 26.5-40GHz (waveguide) £600
5370B universal time-interval counter £2500
6253A dual power supply 0-20V 0-3A twice £225
6825A bipolar power supply/amp –20 to +20vdc 0-1A £350
70300A tracking generator plug-in unit £2000
70907A external mixer for 70000-ser spectrum analyser £1750
7035B X-Y single pen analogue chart recorder £350
8011A pulse generator 0.1Hz-20MHz £500
8112A pulse generator £2500
816A slotted line 1.8-18GHz with carriage 809C & 447B £500
8350B sweep generator main-frame £2250
8405A vector voltmeter, voltage & phase to 1000MHz £950
8620C sweep generator, many plug-in units available £call
8671A synthesized signal generator 2-6 2GHz £2500

URGENTLY REQUIRED – HIGHEST CASH PRICES PAID FOR 8566B, 8753A/B/C, Spectrum/network analysers. 8590/1/2/3 portable analysers. Please call us if you have high-end capital equipment being under-utilised.

PLEASE NOTE: ALL OUR EQUIPMENT IS NOW OPERATION-VERIFICATION TESTED BEFORE DESPATCH BY INDEPENDENT LABORATORY

We would be pleased to handle all grades of calibration or NAMAS certification by same laboratory at cost price. All items covered by our 90-day parts and labour guarantee and 7-day 'Right to Refuse' (money back) warranty.

ALL PRICES SUBJECT TO ADDITIONAL VAT AND CARRIAGE

CIRCLE NO. 137 ON REPLY CARD

ELECTRONIC UPDATE

Contact Malcolm Wells on 081-652 3620

A regular advertising feature enabling readers to obtain more information on companies' products or services.

The system 2000 is an ideal programmer for the production environment. Fast programming results in high throughput and rigorous verification leads to improved quality control. Single key functions and checks against misoperation facilitates its use by unskilled staff.

MQP ELECTRONICS LTD.
Tel: 0666 825146
Fax: 0666 825141

CIRCLE NO. 152 ON REPLY CARD

NATIONAL INSTRUMENTS 1995 CATALOGUE

The 1995 National Instruments catalogue describes more than 900 software and hardware products. Engineers and scientists can use these to develop integrated instrumentation systems for test and measurement process monitoring and control, using industry-standard personal computers and workstations.

NATIONAL INSTRUMENTS FOR FURTHER INFORMATION CALL 01635 523545

CIRCLE NO. 153 ON REPLY CARD

1995 MASTER PRODUCT CATALOGUE NOW OUT!

Test and Instrument control solutions. 48 pages of full description and technical data on our own range of solutions to your PC and PS2 interfacing problems; IEEE488 (GPIB) * DIO * Timer/Counters * RS232 * RS422/485 * A/D * D/A * plus Opto Isolated versions. New Parallel/Serial RS232, Opto Dual RS232, Motion Control, Converter and Repeater for 1995!
ISO 9001 Quality guarantee ✓
UK design and manufacture ✓
36 month no-quibble warranty ✓
Telephone hotline support ✓
Competitive pricing on the page ✓
Intelligent solutions — friendly service ✓

BRAIN BOXES
Unit 3f Wavertree Boulevard South
Wavertree Technology Park
Liverpool L7 9PF

CIRCLE NO. 154 ON REPLY CARD

COMPACT AND LOW COST EPROM ERASER

- Capacity for up to five 24/28/32-pin DIP devices or four 40-pin DIP devices
- Adjustable timer: 0-60 mins
- Anti-static foam lined device drawer
- Power indicator lamp
- Safety interlock on drawer – prevents accidental exposure to U-V light

Stag Programmers Limited
Martinfield, Welwyn Garden City, Hertfordshire AL7 1JT, UK
Tel: 0707-332148
Fax: 0707-371503

CIRCLE NO. 155 ON REPLY CARD

Programming Solutions

SMART Communications offer the best range of low cost programmers for your every need. Unrivalled device support includes the latest MACH, pLSI, MAPL, PIC, WSI, Atmel, Xilinx and Intel parts.

ALL-07 Universal Programmer

Pin driver expansion can drive up to 256 pins.
Supports over 2000 IC's – 3 and 5 volt devices.
EPROMs, E²PROMs, Bipolars, Flash, Serial EPROMs up to 16 Mbits parts, over 150 Microcontrollers and PLDs, EPLDs, PEELs, PALs, GALs, FPGAs etc...
Universal DIL (up to 48 pins), PLCC and gang PACs – significantly reduces the number of adapters required.
Powerful full colour menu system.
Connects to the pc printer port with its own power supply.
Latest programming algorithms.
Tests TTL, CMOS and SRAM devices – even identifies unknown parts.
Approved by AMD for their range of programmable logic.

£595

EMP-20 Multi-Device Programmer

EPROMs, E²PROMs, Flash, Serial EPROMs to 16 Mbits.
PLDs, GALs, PEELs, WSI PSDs.
Intel, Microchip, Motorola and Zilog Microcontrollers.
Fast programming algorithms.

£325

Erasers & pin convertors

AT-701 – Chiprase
Ultra-violet eraser.
Very compact
16 chip capacity
Built in timer **£95**

Pin convertors
from DIL to PLCC, SOP, SOIC etc...
from £50

PB-10 Programmer

Low cost programmer.
EPROMs, E²PROMs, Flash and 8748/8751.
Fast programming algorithms.
Simple but powerful menu driven software.

£139

SMART Communications have a full range of dedicated programmers for the Microchip PIC range of microcontrollers – both single and gang for DIL and SOIC variants.

We also supply a wide range of development tools – Assemblers, Compilers, Simulators and Emulators – for a wide range of microprocessors, especially the Microchip range. Our ROM emulators start at just £99.

SMART COMMUNICATIONS

2 Field End • Arkley • Barnet • Herts • EN5 3EZ • England
Telephone +44 (0)181 441 3890
Fax +44 (0)181 441 1843

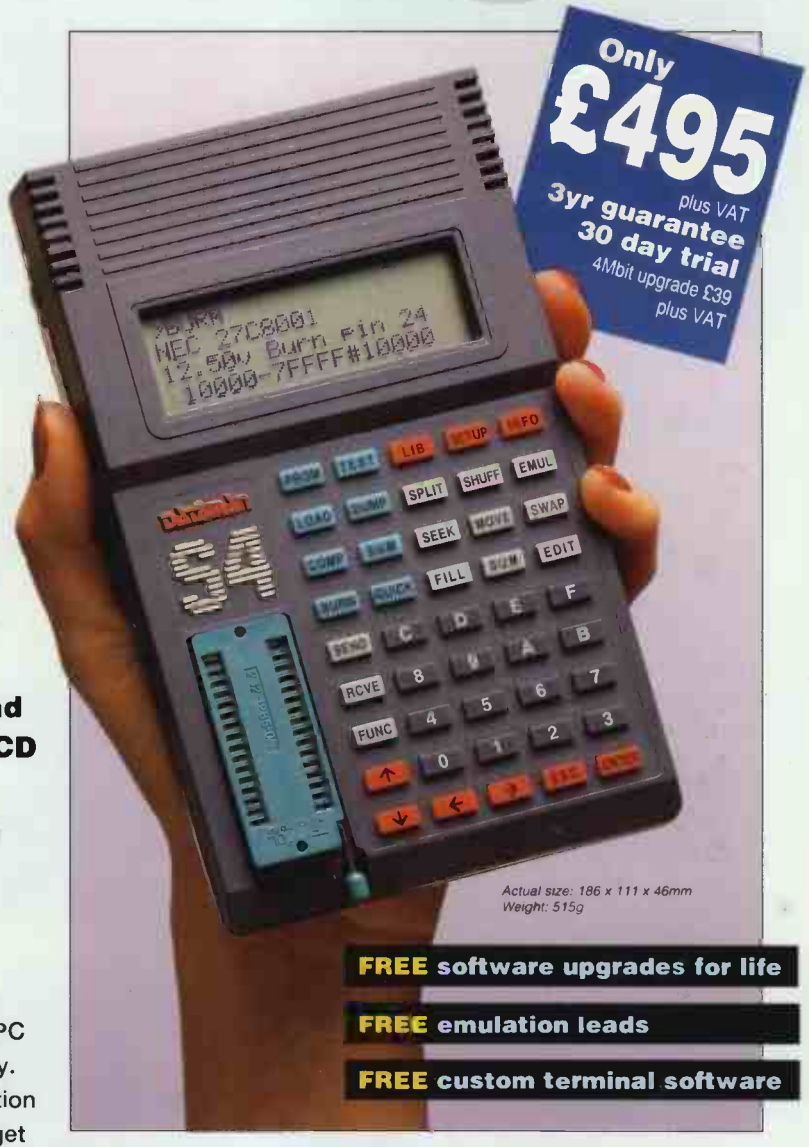
CIRCLE NO. 102 ON REPLY CARD

S4 The best by design!

Credit card holders call now for special bundle deals

S4'S VITAL STATISTICS:

- **Totally handheld programmer/emulator**
- **Fast approved programming algorithms; eg. program and verify: National 27C512 in 16 seconds AMD 29F010 in only 90 seconds**
- **EPROMs to 8Mbit, 5v, 12v and BOOT-BLOCK FLASH, EEPROMs and PEROMs**
- **Three year parts and labour guarantee**
- **Free next day delivery (UK only)**
- **30 day trial available (UK only)**
- **Full 24 byte on-screen editor**
- **Continuous programming whilst charging (nonstop operation)**
- **Moulded designer case - feels as good as it looks**
- **Rubberised colour-coded full travel keypad**
- **Big, easy-view 80 character supertwist LCD**
- **Optional modules available to program PICs, 8751, 16-bit EPROMs, Toshiba 4-bit, Hitachi H8**
- **Optional sockets for programming and emulating PLCC devices**



S4's 32 pin ZIF socket programs a huge library of 8 & 16bit EPROMs, EEPROMs, FLASH, PICs and other popular microcontrollers using manufacturers approved algorithms. Our free and easily updatable device library enables users to always have the latest software installed. During our sixteen years of designing and selling innovative and fast programming solutions to industry, Dataman has *never* charged for software updates or technical support.

Built in emulation enables you to see your code running before committing yourself to an EPROM. Load your program from an EPROM or download code from your PC into S4's memory. Plug S4's emulation lead into the target system, press the emulation key and run the system. Changes can be made using S4's powerful editor, and you can re-run the code to test and confirm changes. When the code is proved to be working, it can then be programmed to a fresh ROM.

The S4 package comes complete with mains charger, emulation leads, organiser-style instruction manual, PC software and a three year guarantee.

S4 is always available off the shelf and we ship worldwide on a daily basis. Call now for delivery tomorrow!

Bona-fide UK customers can try S4 for thirty days without risk. 18,000 satisfied users worldwide can't be wrong!

CREDIT CARD HOTLINE 01300 320719 for same-day dispatch

DATAMAN

Dataman Programmers Ltd

Station Road, Malden Newton
Dorset, DT2 0AE, UK.
Tel: 01300 320719 Fax: 01300 321012
Telex: 418442 BBS: 01300 321095
Modem: V.34/V.FC/V.32bis

22 Lake Beauty Drive, Suite 101
Orlando, FL 32806, USA
Tel: (407) 649-3335 Fax: (407) 649-3310
BBS: (407) 649-3159 24hr
Modem V32bis/16.8K HST

CIRCLE NO. 103 ON REPLY CARD